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History of the Reaction Breakwater at Aransas Pass, Texas.*

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Publicity and Patriotism are the Bulwarks of a Republic.

Conservatism is not always the handmaiden of Progress as may be seen from the opposition which has attended the efforts to introduce an economic agency into the service for the utilization of natural forces for the improvement of commercial channels.

Early in 1887, the writer, under a *nom de plume,* submitted to the American Philosophical Society a thesis, entitled *"Physical Phenomena of Harbor Entrances,"* to secure a disinterested analysis of its merits, by experts, and nine months later, or on the 16th, of December, the Society awarded to its author the highly prized "Magellanic Premium for his Discovery in Physical Hydrography and his Invention of a System of Harbor Improvements." Immediately thereafter the plans were presented to the United

*Read by title.

States Board of Engineers, which filed a report in the War Department, dated March 16th, 1888, concluding in these words:

"The views are purely theoretical, are unconfirmed by experience and contain nothing not already well known, and which has a useful application in the improvement of our harbors."

No copy of this report, so adverse to the findings of the Philosophical Society, was sent to it or to the author, but was accidentally discovered some months later when a communication was mailed to the Chief of Engineers requesting permission to establish the truth of the so-called "theory," and asking for the citation of a precedent, in these words:

Gen'l Jas. C. Duane, Chief of Engineers.

June 30, 1888.

Dear General:—

I have the honor to forward herein a copy of my Reply to the Report of the Board of Engineers. . . . Since I believe the plans to be new, and hence unprecedented, it would doubtless be satisfactory to the Board, as well as to myself, if an opportunity were given me, to make a test, or to be referred to a similar construction which has failed. If there be none, it would be a valuable contribution to the profession to have a record of the facts from experience. I have therefore the honor to request that you will recommend, with the approval of the Board, if you so desire, that a trial be made, at a site to be agreed upon by the parties interested, in securing deep water."

On September 14, a letter was mailed to his successor, General Casey, making a similar request, and copies of the "Reply" were sent to all the members of the Board, but none of these communications elicited an acknowledgment.

This heritage of prejudged condemnation and opposition to demonstration has characterized all of the six succeeding administrations, to the present time, and although Congress subsequently intervened, at a late date, to require a test to be made, it is now proposed to destroy the automatic results which have been secured, prior to the establishment of the equilibrium of the active agencies, as will appear from the sequel as set forth in this brief narrative of events.

In the Historical Résumé herewith, (Appendix "A") it is shown that from 1853 to 1879 (26 years) the Government hesitated to undertake work at Aransas Pass because of the reported existence of quicksands, constituting an "insuperable objection to

any such experiment," yet on the latter date it was estimated that a channel of *twelve* feet deep might be secured for $759,185 by the use of two jetties, and the southerly one was commenced in 1880.* Up to May, 1889 (10 years), there had been expended on this work $550,416 with "insignificant results" when it was suspended. Before suspension, however, it was modified to provide for a twenty-foot project, estimated to cost $2,052,543.72. It has been shown also that the work done under the Aransas Pass Harbor Co., holding a franchise from the Government, which it succeeded, rapidly scoured out the bar until the old jetty previously built and reported as having disappeared, was discovered to be in

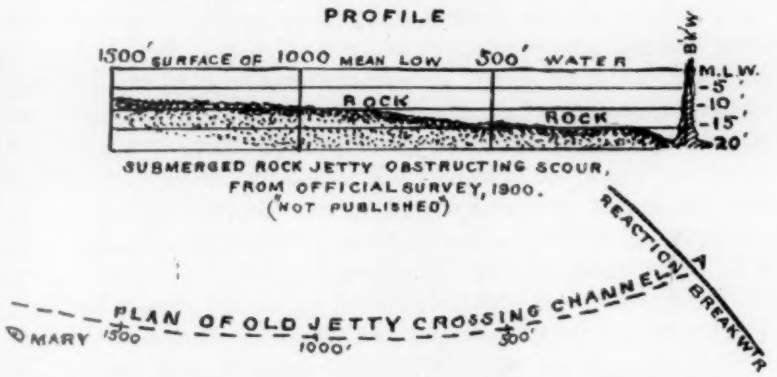


Fig. 1. Plan and profile of old government jetty between wreck "Mary" and the reaction breakwater, showing depth to rock, which prevented scour by acting as a submerged dam.

place at a depth of eight to fifteen feet, and lying directly across the channel, where it intercepted the currents and prevented further deepening, and that Congress passed the act of 1899, requiring the obstructing jetty to be removed, the work to be done in such a manner as to in no wise interfere with the curved jetty now located in said harbor. (See Fig. 1.)

It was unfortunate that this act was so worded as merely to "authorize the Secretary of War to contract for the removal," &c., so that the work was authorized and advertised September 25, 1899, at which time it was hoped that this obstruction would finally be removed and the currents be free

*Genl. Craighill, a member of the Board, objected, as he did "not coincide with the views of the officer in charge in general application or in particular at this locality," and believed that one jetty would suffice.

to complete the scouring of the channel. This same act also provided that the private corporation should surrender its franchise and the breakwater already in place at a cost to it of over $250,000, merely on consideration of the continuance of the work, and such transfer was made March 27, 1899. The Government then let the contract for the removal of the old jetty, but did not require the contractor to execute it, as it was claimed that a survey made showed it to be no longer an obstruction.

This survey covered the months of October, November and December, 1900, when 529 borings were made along the site of the old Government jetty which crossed the channel. Most of these borings only went to the rock, covering the mattress foundation, but a few were sunk to a depth of twenty feet. The map was not published, but it showed the existence of rock in place entirely across the channel at depths of from eight to fifteen feet, yet the opinion was officially published that this old sill "was no longer acting as an obstruction," and it was allowed to remain. Another act of Congress was required ordering its removal, and as the sequel shows, the last of it was not taken out until *six* years later. It constituted a serious obstacle to scour. (Fig. 1 ante.)

After thirteen months delay the Government released the contractor and requested permission of the Judge Advocate General's Office to apply the appropriation to work on the curved jetty (prohibited by the act), which it authorized on the ground that having made a contract for the removal of the old jetty, the law was satisfied. The opinion of the Judge Advocate General upon the case as submitted to him by the War Department reads in part as follows: "Whether in view of the language of the act the removal of the old jetty can be postponed, and the money appropriated be applied to the work of jetty repair and construction?" . . . to which query the reply is made, "In my opinion the act is not to be construed as requiring the removal of the portion of the old Government jetty specified therein, but as authorizing the Secretary of War to contract for its removal . . I am of the opinion that the entire appropriation can be expended for other improvements. (See Appendix "B" for more complete extracts.) The work was then, after several years of delay, let for the building up of the *inner* end of the breakwater, in violation of the design and to its injury, by causing erosion inside of

the bar and rolling it forward, which effect was to have been avoided by constructing from the outer end shoreward. This advance of the bar, with the old jetty, still in place, caused a deposit extending seaward for about a quarter of a mile with depths of thirteen to fifteen feet, there being over twenty feet at nearly all other points. (See Fig. 2, Profile of 1902.)

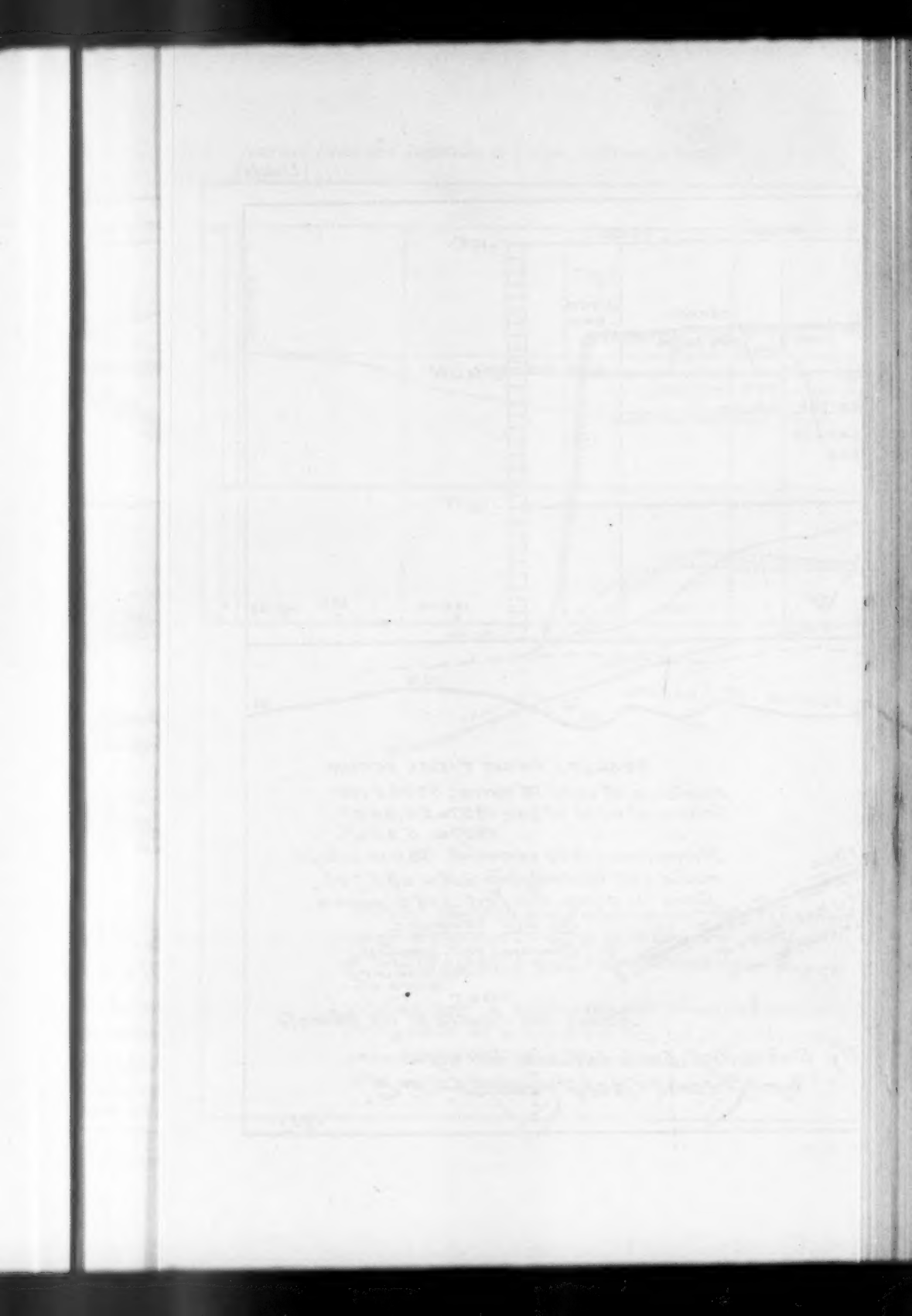
This condition of affairs made it necessary again to appeal to Congress, and accordingly, in 1902, a proposition was submitted by the Reaction Jetty Company with a memorial (see Appendix "C") offering to complete the work on the reaction breakwater and guarantee the channel for the sum of $500,000, accompanied by large bonds and forfeitures, in case the contract was awarded to that company, and to finish the same within two years. The River and Harbor Committee was unanimously in favor of its acceptance, but the item was submitted to the Engineering Department for its opinion, which was not only adverse but it was accompanied by a communication without date or signature, containing serious errors of facts, and an offer was also made by letter to place a dredge there and create the channel by that means for $100,000. It was furthermore stated that if the proposition of the company were accepted by the Committee the entire bill would be defeated, and under this view of the situation the Committee did not feel warranted in authorizing it to be done, but referred the responsibility to the Senate Committee on Commerce. Here it was opposed by the Member of Congress from the district, who refused to read the proposition, as well as by the former Harbor Company, because it had received no consideration from the Government for its previous work. While the Committee was favorably inclined toward the acceptance of the proposition to award the contract directly, it was informed by the Engineer Department that it would establish a dangerous precedent, but an agreement was made that "if Congress wished the plan tested it would be carried out by the U. S. Engineers in good faith." Accordingly the plan and rights were turned over to the Department with an appropriation of only one-half of the amount necessary to complete it. In view of the sequel the language of the act passed June 13, 1902, is important. It reads as follows:

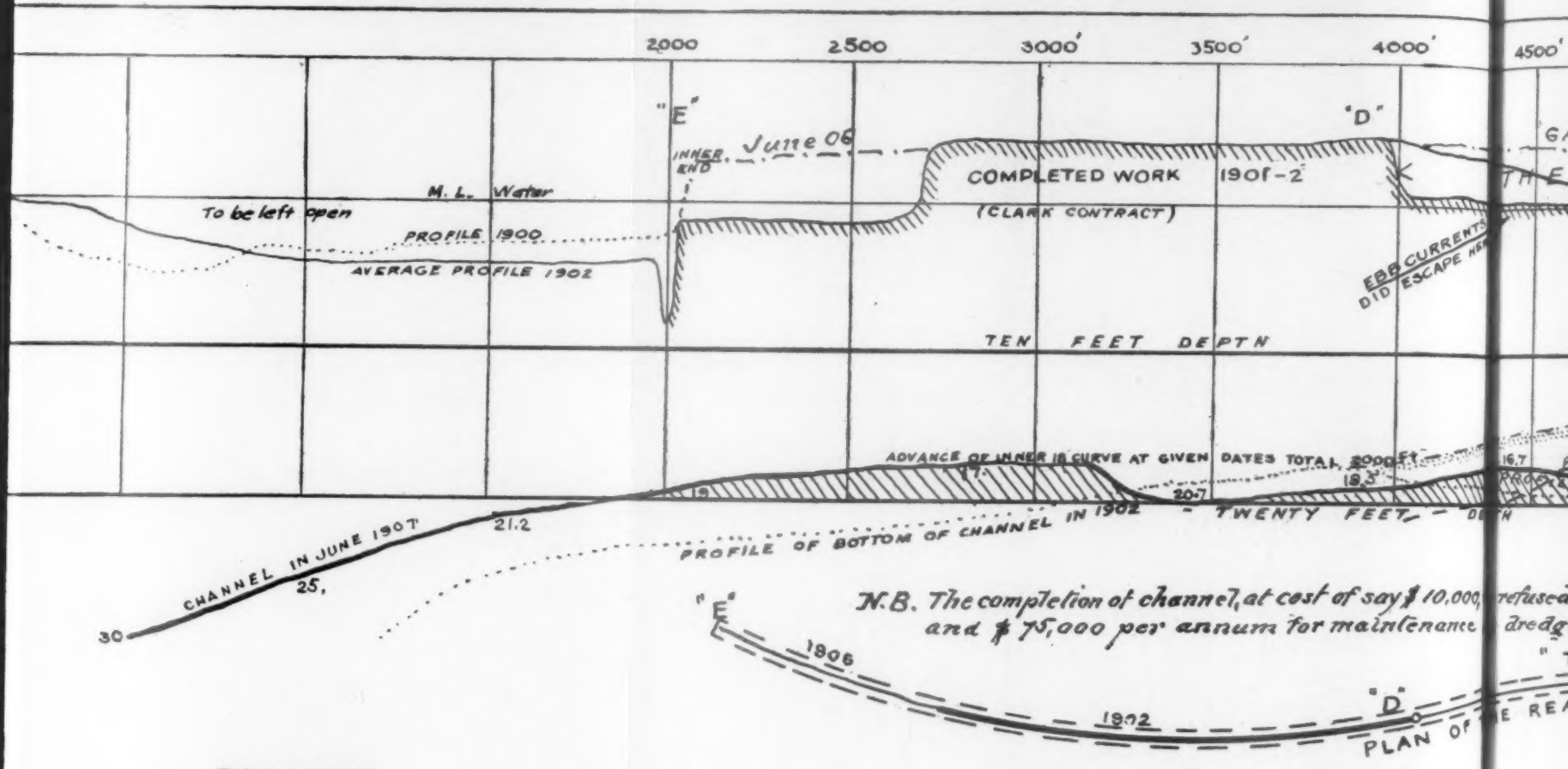
"*Improving Aransas Pass, Texas.* Continuing improvement

$250,000; Provided, That the work at this harbor shall be confined to the completion of the north jetty in accordance with the design and specifications of the Aransas Pass Harbor Company, and in continuation of the work heretofore carried out on said jetty by said company, and to such additional work as may be necessary for the strengthening of such jetty, and for the removal of such part of the old Government jetty and any other hard material which may interfere with the formation of a channel by the natural action of the currents."

The clause herein providing for the "strengthening of such jetty" would have enabled the Government to enlarge the dimensions and height of the breakwater, thus adding greater pressure on the base, offering more resistance to wave action, without controlling more current, but increasing the cost and liability to deterioration, as well as the time to complete, as was shown in the specifications subsequently issued, which added twelve per cent. to the sectional area of the structure—without corresponding benefit.

Soon after its passage an offer was made to assist in the preparation of the specifications so as to have them conform to those of the Company, but it was declined. When they were issued it appeared that with the exception of the citation of the act, there was no reference to the plans and specifications of the Aransas Pass Harbor Company's method or plans contained therein, so that it became necessary to call official attention to this departure from the express terms of the act, and the Secretary of War required them to be recalled and modified accordingly, which was done merely to bring them into substantial accord with the plans of the Aransas Pass Harbor Company to avoid further delay. The next move was a proposition to reject all bids on the allegation that they were excessive, but before doing so a former U. S. civil engineer, having faith in the plans and desiring to have the demonstration completed, a man who had been in charge of the Galveston works for nearly twenty years, offered to undertake this work at a lower figure, and his bid was accepted, after he had first filed his bonds to take the contract. It was divided, so that $50,000 of the money was made available for the removal of the old jetty, given to another party, and the balance, $200,000, for the continuation of work on the breakwater, thereafter called





ECONOMY.

Prior to 1890 the Government had expended over $ 500,000 in efforts to secure 12 feet with "insignificant results", and abandoned the work.
It has now a self-created channel, readily navigable at a cost of less than $ 500,000 created by this Reaction Breakwater.
Old jetty removed 1904, from channel.

TIME

With a 14 inch diurnal tide, without aid from dredging about 3 years would be required after completion, yet only one has elapsed, nor is the original design completed.

PROGRES C

1902 - Old Go Jetty in place, hel depth
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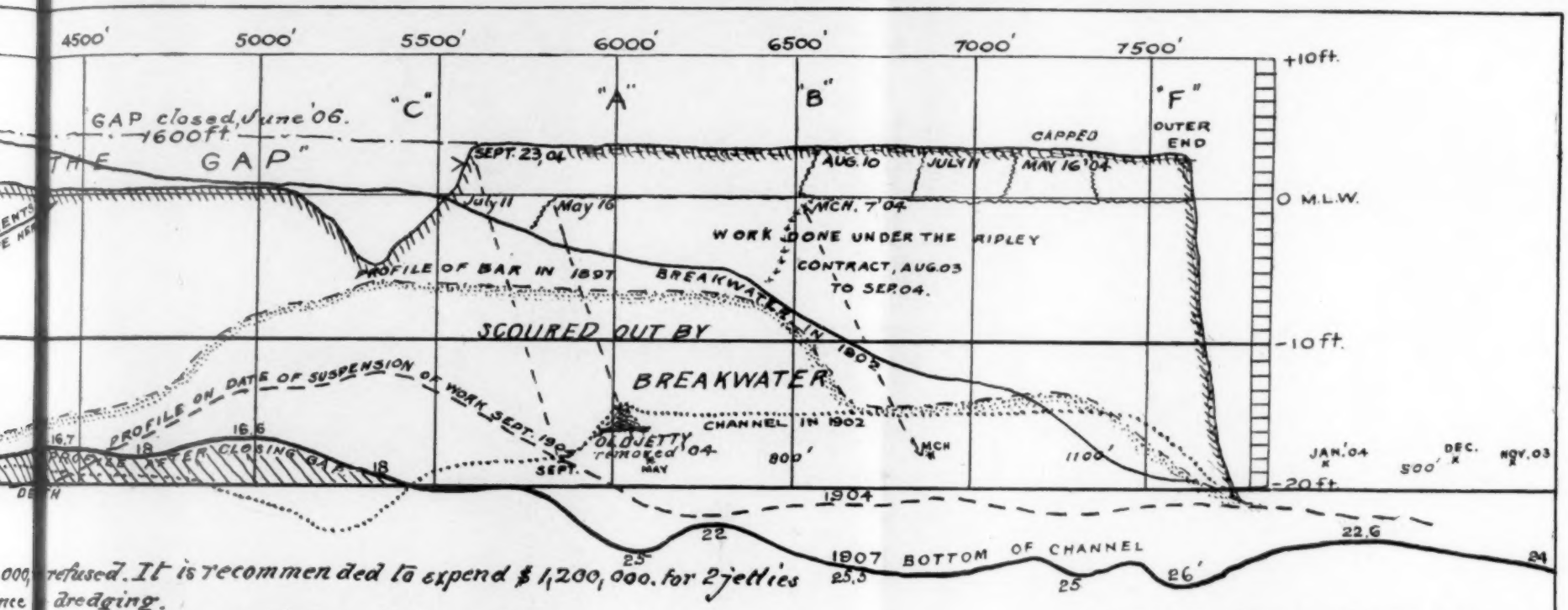
Fig. 2. Progress chart and profile showing the recession of bar by rapid scour as work at outer end proceeded and shoal from failure t gap prompt



refused. It is recommended to expend $1,200,000. for 2 jetties
dredging.

"THE GAP" 1906 "C"

"A"

REACTION BREAKWATER

"B" 1904

DEEPENED TO OVER 20 FT. BY NATURAL SCOUR, BY FEEBLE TIDE, ONLY PARTIALLY CONTROLLED

"F"

RESULTS FROM TIDAL SCOUR.

Recession of outer 18' curve, 3300 feet.
Sectional area of bar, 1897 = 24,840 sq'
" " " 1907 = 5,356 sq'
Remaining to be removed. 38,000 cub. yds.
would cost by dredging @ 15 ct = $5,700.
Gain in depth, ten feet, 150' wide +
No bar advance
Channel self-created.
and self-maintained.

COST.
About one-fourth of U.S. estimate.

S CHART of ARANSAS PASS.

Gulf Jetty (ordered to be removed in 1898) still
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Respectfully Submitted from Official Surveys.
by Lewis M. Haupt. C.E.
1907

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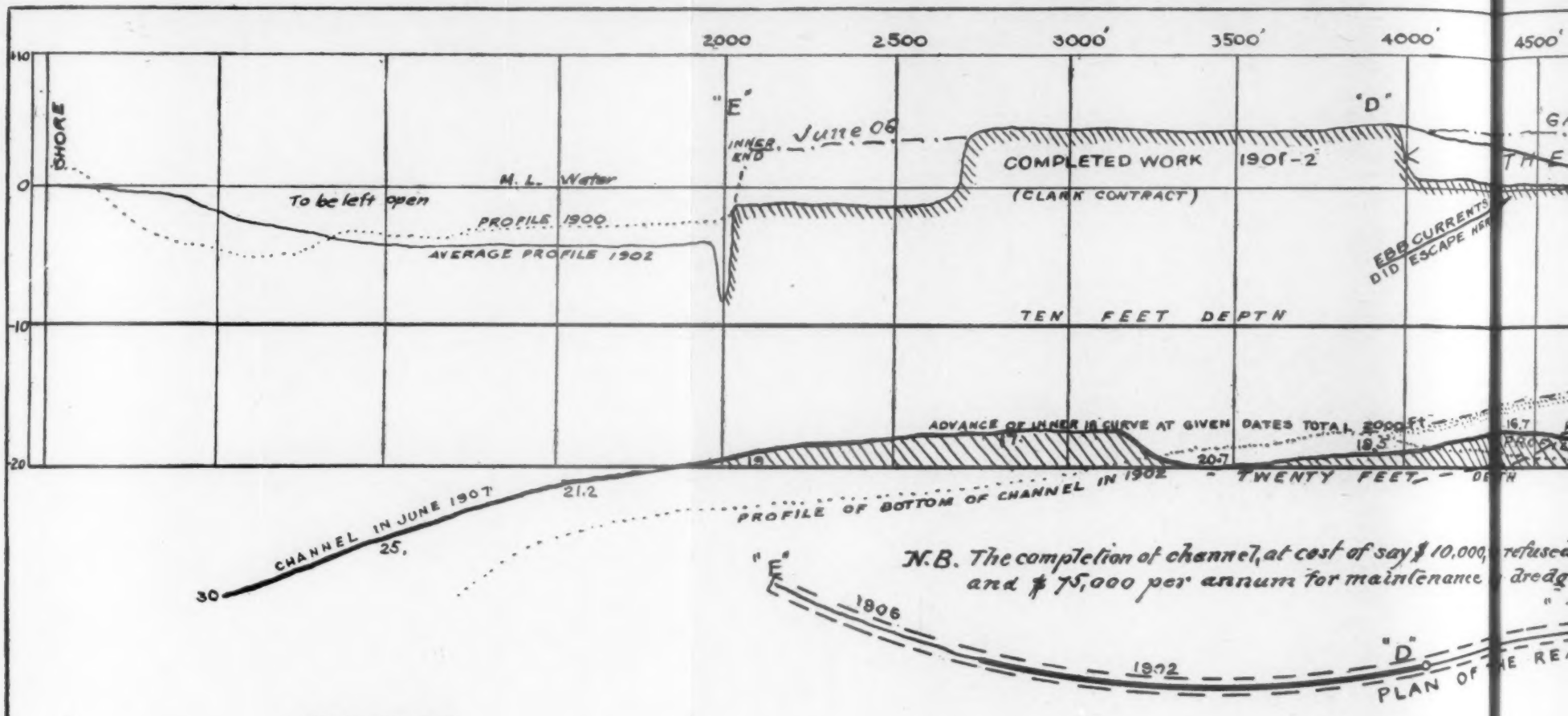

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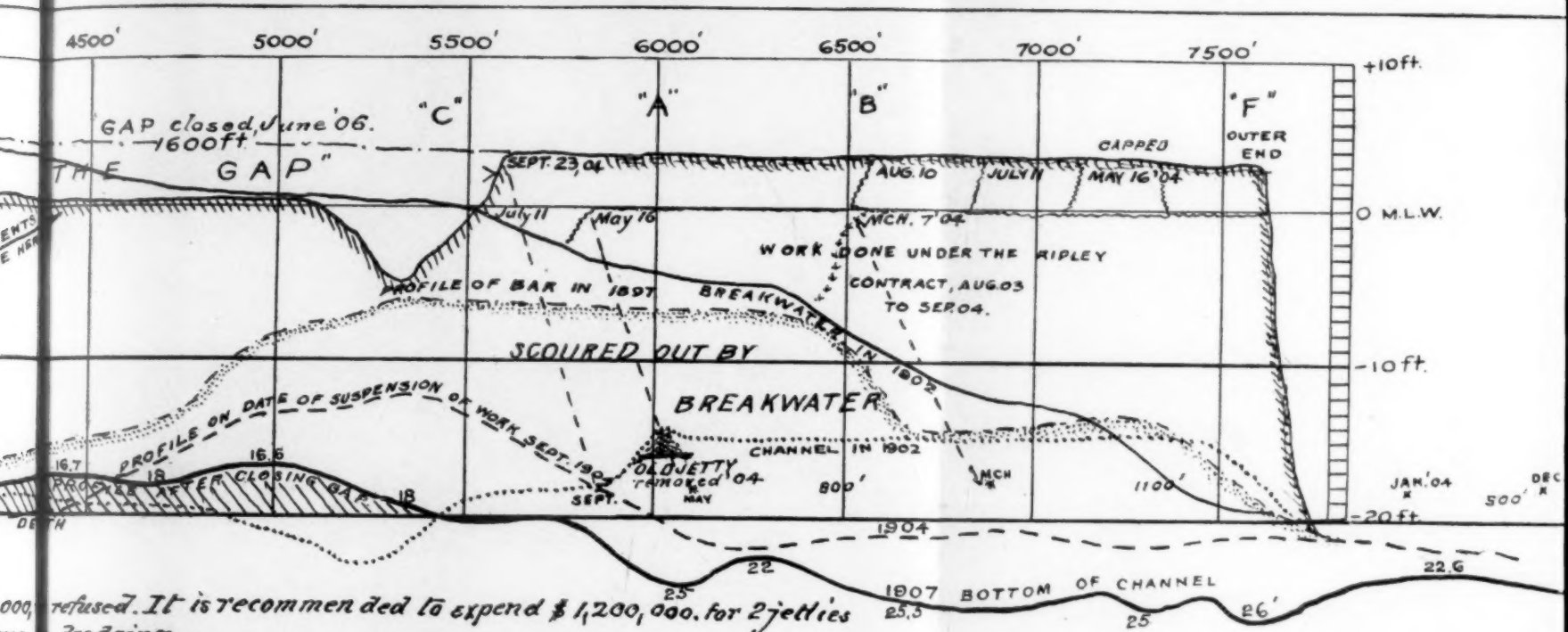

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the "north jetty," by the Government, beginning at the outer end, in the open sea, and extending shoreward.

The contract was finally awarded him and the work was commenced in August, 1903, after a series of mishaps to his plant and the wrecking of his tug, the refusal of the Government to permit the capping to be placed for nine months, the rejection of blocks, &c. But space does not permit the recital of the detailed obstacles which beset his path, from beginning to end, including the quarantine from yellow fever. It is the result which is the subject of this recital, and the difficulties which attended the demonstration from beginning to close. His work was faithfully performed and the appropriation of $200.000 was exhausted by September of 1904, by which time the outer half mile was completed. The old jetty was also *reported* as finally removed under the separate contract, by blasting but without dredging, so that the currents were partially freed after nine years, to work upon the bottom of the channel, yet they were not fully under control, for there was a gap left in the middle of the breakwater between the portion previously built at the inner end in violation of this plan, and the work just finished, of 1600 feet, through which the ebb currents escaped and the sand entered, thus forming a shoal with about sixteen feet depth upon it at low water. (See Fig. 2.)

RESULTS OF OUTER CURVED PORTION OF BREAKWATER.

As fast as the work was raised to the surface the scour became marked, the contours receded rapidly, cutting out a channel of over twenty feet and throwing the material over to the westward, building up a counterscarp automatically, and leaving an ample width under the lee of a perfect and continuous aid to navigation. These progressive changes are shown in the accompanying profiles of the thalweg of the channel and the breakwater with dates attached, indicating the relation of the work as it progressed to the depths secured. At this juncture a general emergency bill was framed with the expectation that it was to provide for the closure of "the gap," and the contractor had consented to continue work while his plant was on the site, upon the same terms, but the Department finally concluded that this work did not fall within the purview of the act passed April 28th, 1904, for the

"restoration or maintenance of channels." The first objection made was based on the assertion that this was not a Government work, although it had been conveyed to the United States and Congress had made an appropriation for its continuance, but when this position was shown to be untenable it was thus claimed by the Government Engineer that "no such deterioration had occurred as to justify an apportionment." The sequence of this refusal to close the gap was that the work was suspended and left in an unfinished condition for a year longer, or until another bill could be passed. The policy of the Department is clearly stated in a letter from the local officer in charge to the Chief of Engineers, written May 31st, 1901, or more than two years after the work done under the patent had been conveyed to the Government. The letter states; "So far as I am informed, there never has been any proposal on the part of the United States to make use of Professor Haupt's patent at Aransas Pass. Existing projects for that locality are based upon the plan of a Board of Engineers, which contemplates the use of two jetties, is radically different from the plan of Professor Haupt, and cannot therefore infringe on his patent. . . . The United States has not used his patent there, nor does the existing project contemplate its use." Yet this Board of Engineers, in its report, so modified its two-jetty plan (see Fig. 3) as to provide for the removal of a "small part of the curved breakwater and utilization of the balance, as it would cost less than the approved Government plan," but notwithstanding this embodiment of $250,000 of jetty work and the removal of several hundred thousand yards of sand from the channel by natural scour it reported that the value of this work to the Government "is nothing," and took it over without consideration as an essential part of the proposed "north jetty." (Vide, Doc. H. R., No. 137, 55th Cong. 2d.) Still further, it was recently testified by the officer in charge at Galveston, that on July 14, 1902, the Acting Chief of Engineers . . wrote to his predecessor as follows:

"The item for Aransas Pass does not mean that Congress has adopted the Haupt plan further than that a fair trial of the plan of the Aransas Pass Harbor Company is desired. Mr. Haupt made a strong appeal to the Committee of the House for a contract to complete his work for the sum of $500,000 . . . Many

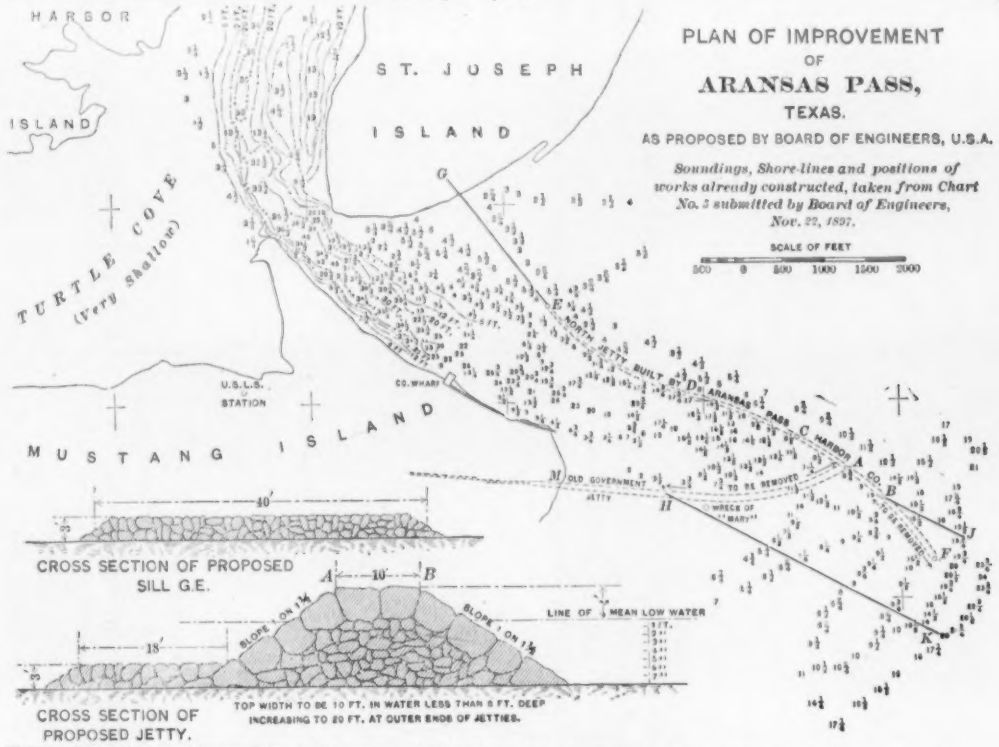

HARBOR
ISLAND
ST. JOSEPH
ISLAND
TURTLE COVE
(Very Shallow)
MUSTANG ISLAND
U.S.L.S. STATION
CO. WHARF
NORTH JETTY BUILT BY ARANSAS PASS HARBOR CO.
OLD GOVERNMENT JETTY TO BE REMOVED
WRECK OF "MARY"
PLAN OF IMPROVEMENT
OF
ARANSAS PASS,
TEXAS.
AS PROPOSED BY BOARD OF ENGINEERS, U.S.A.
Soundings, Shore-lines and positions of works already constructed, taken from Chart No. 3 submitted by Board of Engineers, Nov. 22, 1897.
SCALE OF FEET
500 0 500 1000 1500 2000
CROSS SECTION OF PROPOSED SILL G.E.
40'
10'
18'
SLOPE 1 ON 1½
SLOPE 1 ON 1½
LINE OF MEAN LOW WATER
CROSS SECTION OF PROPOSED JETTY.
TOP WIDTH TO BE 10 FT. IN WATER LESS THAN 6 FT. DEEP INCREASING TO 20 FT. AT OUTER ENDS OF JETTIES.

Fig. 3. Embodiment of the reaction breakwater in the two-jetty plan, as proposed by the government, at an additional mated cost of $1,525,000, and later with $75,000 annually for maintenance.

of the Members appeared to desire a test, and the wording found in the act was prepared by an officer of this office with a view and a promise that a full and fair test of the Haupt scheme for Aransas Pass should be provided for." . . . "The item regarding the removal of the old dam was also introduced with an object; it was claimed that such remnant of dam interfered with the full result, and its removal was promised." The officer of the district also testified that he gave interviews to the press reporting that the work was a failure, even when it was far from complete and before this obstructing "dam" had been removed, and that the two-jetty plan was essential to success.

In this connection it may be well to state that to establish its priority and form the basis for the organization of a Company to make tenders to carry out the work of economically improving our harbors upon the "no cure no pay" plan, as was done by Capt. Eads and others, a patent was applied for and granted in 1888, and under it a million dollar company was organized and tenders made without charge for any royalties for use of patents for the opening of the channels at the mouths of the Columbia, Mississippi, Hudson and other rivers (see Figs. 4, 5), which proposals were accompanied by guaranteed depths of thirty-five feet by natural scour, and which had they been accepted, would have saved to the Nation not less than $20,000,000 in the cost of construction and a larger sum for maintenance. These proposals were referred to the Boards of Engineers, which rejected them, suppressed the tenders from the reports made to Congress, and also declined to permit the Company or its officers to inspect their findings, although the Secretary of War had agreed to a rebuttal. In consequence the Reaction Jetty Company was dissolved. On the third of March, 1905, an appropriation of $100,000 was made to continue the work upon these plans, the language being: "Provided further, that the amounts herein appropriated and authorized shall be applied to the completion of the project in accordance with the design and specifications of the Aransas Pass Harbor Company, and in continuation of the work heretofore done, and to such additional work as may be necessary for strengthening the jetty." Under this act the work was resumed August 9th, 1905, and "completed" June 11th, 1906. The report for that year published a map showing a minimum depth of over sixteen feet, at

Fig. 4. Location of reaction breakwater for mouth of Columbia river, Oregon. (See black concave curve.) Channel over 35 feet for $2,500,000. Guaranteed. The deep channels are the natural reaction depths cut by currents.

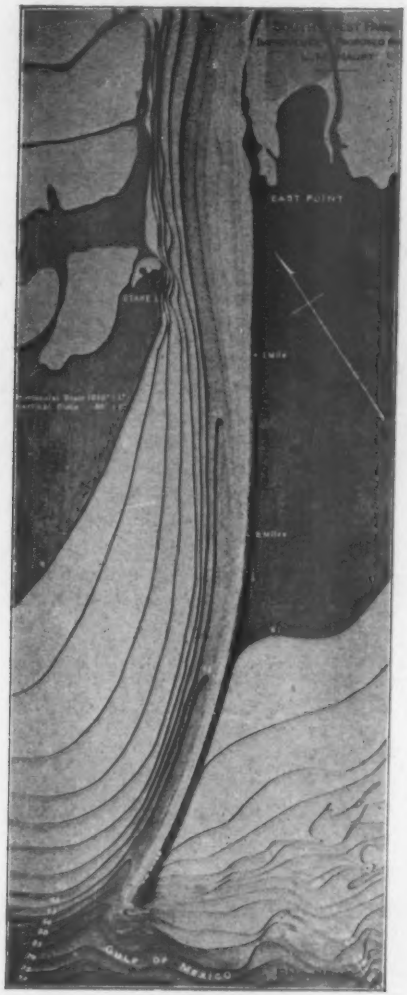


Fig. 5. Reaction jetty as applied to the mouth of the Mississippi at Southwest Pass, guaranteed to create an automatic 35-foot channel for $6,000,000, with over 100,000,000 cubic yards of sediment moving gulfward annually.

only one point in the channel, abreast of the former gap, and considerably over twenty feet for the half mile at the outer end, completed in 1904. It gives no description of the channel nor its great improvement over the original six feet, other than to state that "a rock lump with 16.5 feet of water on it was brought to the attention of this office near the close of the year. It is believed to be a part of the old Government jetty overlooked by the inspectors." The present report (1907) from the new local officer states that this lump has been removed, but it is silent as to the depths or condition of the channel, and although a survey was made in June, 1907, showing still further deepening and improvement, it is not published. (See Figs. 6, 7.) On the contrary, within about six months of the closure of the gap a Board of Engineers was called upon to report upon the conditions at the Pass, and on the 6th day of December, 1906, after a visit to the site and public hearings, it stated that "The Board has not sufficient information upon which to base an opinion as to what is now the best method to be pursued to obtain a suitable entrance channel across the bar, nor what the cost of such a channel would be, nor as to the probable location of and the means of connecting the deep water of the Pass with the commercial port that may be expected to develop. Such data can be obtained only by an additional examination and survey, which is recommended."

Thus it recognized that there was a "*deep water*" *channel* at the Pass which it was desired to connect with the proposed new terminals in the bays, and that a survey is necessary before a plan and estimate can be submitted.

This report was apparently so unsatisfactory to the Department, however, that the Board was instructed to re-examine the subject, and on the 22d of the same month it reported on some data sent to it by the officer in charge of the district, in favor of a return to the original two-jetty plan of 1887, without stating reasons or alleging any failure of the reaction breakwater, which had not even yet been completed as designed, nor had there been sufficient time for the channel to have been fully formed by the natural scour of the currents. The Board approved the recommendation, and the rough estimates amounting to *more than a million dollars,* but made the significant suggestion that in its opinion sufficient time had not elapsed for the effects of the work to become manifest and placed the responsibility upon Congress,

accompanied by a preliminary appropriation in the bill of $490,000 for the beginning of this work on the two-jetty plan, with an estimate of $75,000 *annually for dredging*, which had been rigidly prohibited hitherto. Thus the work of destruction of the breakwater was inaugurated. At that time no survey had been made since the previous June (1906), when the rock from the old jetty was found limiting the depth to 16.5 feet, while the channel was, and still is, steadily improving. In addition to this the bill carried nearly $300,000 for interior channels from Aransas Pass to Corpus Christi and Cuero, due to the additional depth already available across the bar in consequence of the scour from this work, upon which only about $500,000 in all appears to have been expended by the Government, instead of over two million, as originally estimated.

Moreover, before this bill became a law, the Chief of Engineers sent a communication to the Senate Committee, dated February 16, 1907, only eight months after the gap was closed, stating, *inter alia*, that "The work has not been successful in obtaining and maintaining such a channel as was promised."

In this statement he overlooked entirely the qualifications as to the *time* required to develop the channel by natural scour, for when asked by the Chairman of the River and Harbor Committee, in 1902, how long a time it would require, the writer made this reply: . . . "It is unsafe for any man to prophesy . . . but in the light of past experiences and under ordinary conditions, I should say that the deepening might be expected to take place at Aransas Pass at the unusually rapid rate of about eighteen inches per annum, so that to get six feet would require about four years. The process would be slower towards the end of the work in consequence of the longer channel and larger amount of material to be removed as the channel deepens. . . . At Dublin,* the most successful on record, the rate was less than three inches per year. . . . It would be a mistake in my

*Vernon-Harcourt says: "The results of these works (at Dublin) have been most satisfactory, as sown by the profiles of the channels in 1819, 1856, and 1878. Ten years after the completion of the north wall, the bar had been lowered five feet, and in 1861, the total increase in depth amounted to seven feet, and reached nearly to ten feet in 1873." (See Rivers and Canals, p. 239.)

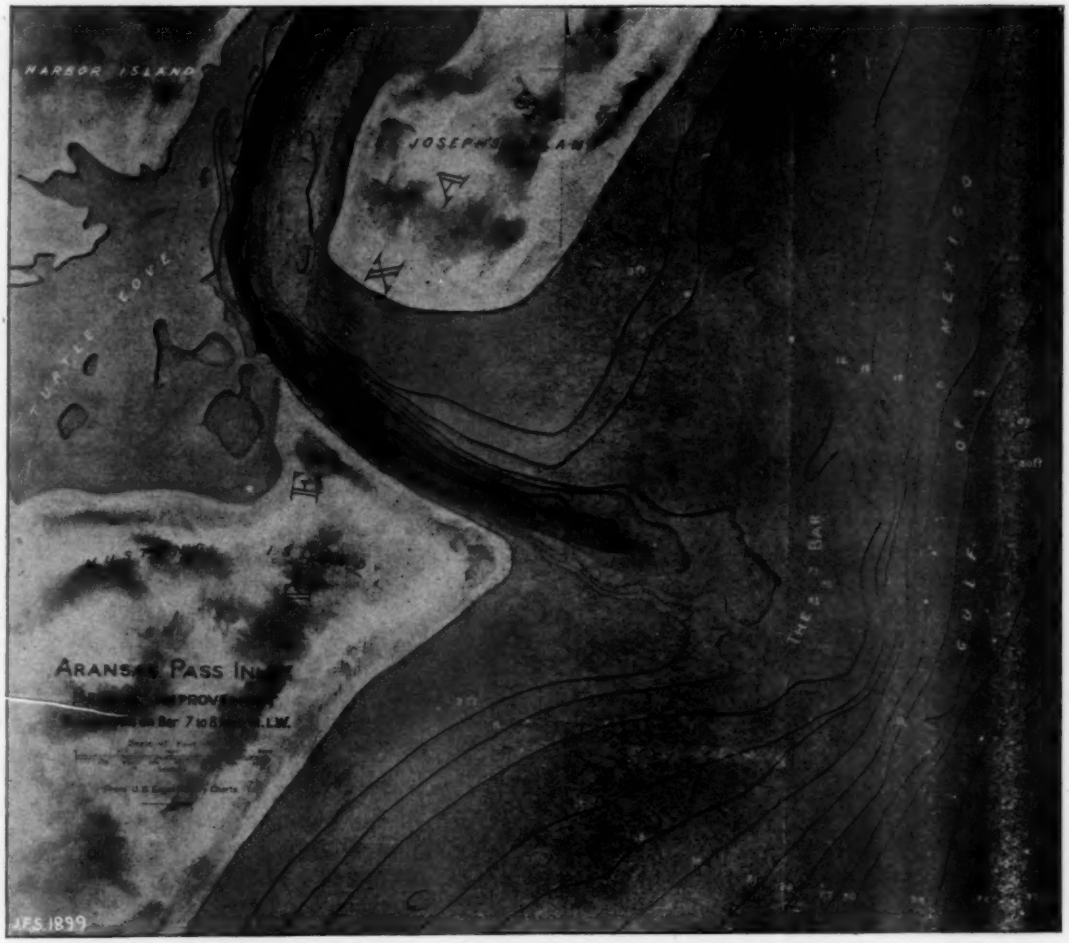


Fig. 6. Condition of bar off Aransas Pass after the suspension of work by the government on the proposed two jetty plan in 1889, the south jetty as built, having been covered with the drift and reported as having "disappeared."

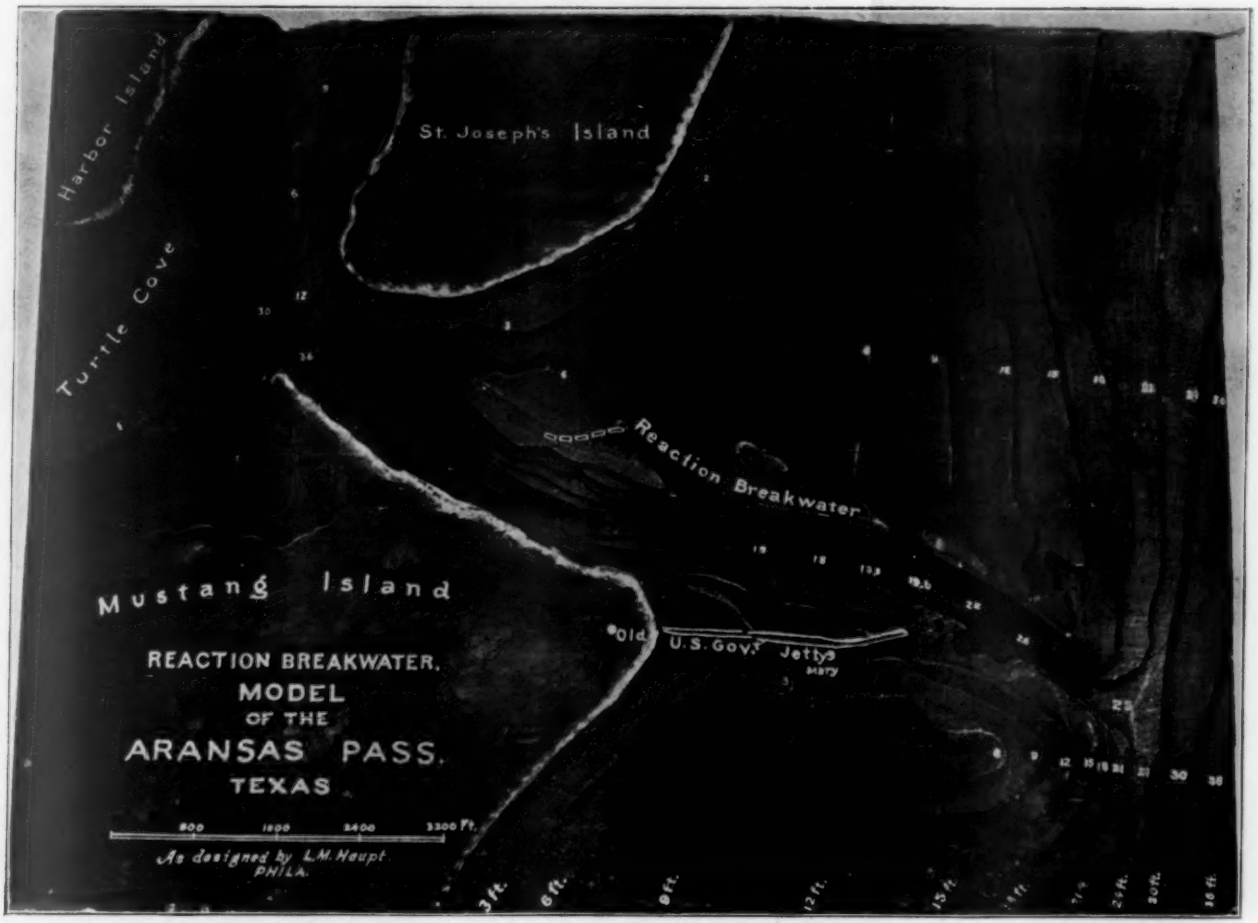


Fig 7. Condition of channel at Aransas Pass after closure of the gap June 11, 1906, and before final completion of breakwater as designed—Channel rapidly deepening and enlarging.

judgment, to tie up the commerce of the country, while awaiting the tardy process of natural erosion, when a little aid (from dredging) would secure immediate and permanent results." But the Committee wished to test the currents and no dredging of the channel was permitted.

At the date of the closure of the gap the depth lacked less than four feet of the predicted twenty, so that at the rate stated of eighteen inches per annum it would have required nearly three years after the work was "completed" before this test could be said to have been fully and fairly made, but as the amount of silt remaining, as shown by the survey, was less than 40,000 cubic yards, which could have been removed for about $6,000 in a few weeks and thus have completed the channel, I requested that Congress make this small amount available out of the appropriation of the $490,000 to hasten the formation of the channel, believing that the remainder would not have to be expended, but this was declined.

Further, the Chief Engineers informed Congress that "In my opinion the adoption of the Haupt plan for improving this harbor has resulted in adding greatly to the expense which will ultimately be necessary before a deep draft* can be obtained." As the original Government estimate, which guaranteed nothing, was in excess of $2,052,000, and as the present estimate to complete, including $100,000 for a dredge, is $1,288,699—and the Government has already expended say $500,000, it would make the total cost by the utilization of the work already done, excluding the dredge, about $1,688,000, or more than $300,000 less than the first estimate, but it will certainly cost far more to create and maintain the channel at $75,000 per year, as estimated, than would be the case if nature were permitted to do the work herself, or if the $6,000 were applied to open it by dredging immediately. He concludes, nevertheless: "Far from Mr. Haupt's plan having in any degree benefitted the Government, I think it has injured it greatly. . . . I know of no other localities at which Mr. Haupt has tried his plan, or accomplished any results. . . . I do not recommend the enactment of any legislation such as he suggests."

*The project was for a twenty-foot draft, and it is expected that the reaction jetty will give about twenty-five or more.—L. M. H.

It is needless to add that no dredging was permitted to remove the small amount of material to complete the channel, in far less time than had been predicted, and under exceptionally unfavorable conditions. During the past year, not only have there been no severe "Northers," so important for scour, but the winds during the summer season have prevailed from the South, driving the beach sand into the face of the breakwater, cutting off about 1000 feet of Mustang Island and rolling it into the channel, yet the last reported depths were from eighteen to over twenty feet all the way across the bar. In fact it was credibly stated, early this month, that the twenty-foot depth had been cut through. This can hardly be anticipated until after another winter at least shall have passed and the inner flank of the Breakwater shall have been constructed as originally designed, to arrest cross-currents.

RESULTS.

As to the measure of success which has been attained by the system so far as it has been completed, it may be well to add that the official reports of the Life Saving Service, stated on August 16th, 1906, or two months after the closure of the gap, that "the breakwater gives a depth of fifteen feet with sufficient width for safe navigation of vessels of such draught." On July 12th, 1907, it is said, "The least depth found on that occasion (in May) was eighteen feet. The tide may have been eight to ten inches above mean low, but it is approximate." This would indicate a gain of over two feet in nine months, covering one of the mildest winters known in twenty-five years.

A Government official, in forwarding a copy of the last survey of June, 1907, volunteers the statement that "It (speaking of the channel) shows large—twenty feet over the bar with some shoaler spots in the upper portion of the channel where the work evidently should be temporarily assisted by the use of a dredge."

Notwithstanding the evidence of Nature and the testimony of disinterested witnesses, as well as the opinions of experts, and the lack of sufficient time to complete the test, it appears that the tragedy is about to be enacted of appropriating a large sum from the National Treasury to put a quietus upon this test, before it could have secured the channel under any possible natural conditions.

UTILITIES OF THE SYSTEM AS GUARANTEED.

Some of the benefits which might have accrued to the Government from its adoption since 1887 may be briefly summarized as follows:

The saving in construction at Aransas Pass, about	$1,500,000
The saving at Galveston, as proposed prior to present plan	6,000,000
Reduction made in estimate at Southwest Pass	7,000,000
Guaranteed plan at mouth of Columbia (see Fig. 4) saving	4,500,000
Automatic training wall for Ambrose channel, saving	1,500,000
Total saving in cost of construction alone	$20,500,000

The cost of maintenance if capitalized at five per cent. would probably aggregate an equal sum.

The Government plans have been radically changed since the submission of this system to Congress, and it is becoming generally the policy to-day, where practicable to build up the *windward* jetty first, beginning at the outer end and building shoreward, thus securing immediate results, although the simultaneous construction of the leeward jetty has the effect of preventing the lateral distribution of material and compelling the bar to move seaward, while the straight form prevents the "continuous reaction" and reduces the scouring effects of the effluent curents.

At the Southwest Pass between 1898 and 1906, the average shoaling for the outer eight miles at the bar, has been 1.55 feet, while the maximum shoaling in channel abreast of Stake Island has been about fourteen feet, and the latest survey indicates an advance of over a half mile of the bar and a still further shoaling on its crest, the ruling depth in the channel being about twenty-one feet with dredges fully employed and the two-jetty plan almost finished. At Galveston, a bar has formed entirely across the 7,000 feet interval separating the jetties and the channel is flexed so that the crossing is now south of the South jetty, with the curvature much sharper than at Aransas Pass. These few illustrations may serve to show the serious nature of the problem of removing ocean bars and the desirability of opening these contracts to any one who may be willing to undertake them under satisfactory safeguards for, as well as from, the Government.

APPENDIX "A."

BRIEF HISTORY OF EFFORTS TO SECURE A HARBOR ENTRANCE AT ARANSAS PASS, TEXAS.

EARLY SURVEYS.

On January 13, 1853, Capt. Geo. B. McClellan reported that the channel over the bar shifted in one week from the north to the south breakers, creating a new depth of nine feet and leaving four feet in the old bed, causing the wreck of three vessels in as many days.

In 1854, a reconnaissance was made by direction of Prof. A. D. Bache, Superintendent of the United States Coast Survey, showing nine feet on the bar, with the inlet extending South-east from the site of the proposed light house on Harbor Island. Since then the inlet has been traveling southwesterly at an average rate of about 260 feet per annum with corresponding deteriorations in channel depths. (One mile in twenty years.)

1869. The first attempt at improvement, made in 1869, was a private enterprise consisting, of wooden hurdles filled with brush and extending for a length of 600 feet from St. Joseph's Island "to cut off a secondary channel." This temporary jetty caused a shoaling of two feet in the secondary and a like deepening in the main channel so long as it remained in place. It was on the *north* side.

GOVERNMENT WORK.

In 1871, Capt. C. W. Howell, U. S. E., forwarded a report from the late Lt. Woodruff, stating:

1871. "The cost of building a jetty from Mustang or St. Joseph's Island towards the bar, which would be able to resist the action of the storms upon the quicksand foundation, must be an insurmountable objection to any such experiment." This opinion was endorsed by Major Howell in these words: "I coincide with Lieut. Woodruff in the opinion that all the plans suggested and discussed by him offer no certainty of producing good results, and that the expense which would be incurred by testing them will be out of all proportion to the benefits derivable from success."

1879. A Board of Engineers reported August 9, 1879, that to obtain twelve feet of water by the plan recommended by it, of two parallel jetties 3000 feet apart, the cost would be $759,185. The depth shown at that date on the chart was seven feet on the crest of the bar. The Board considered that one jetty on the *south* side might suffice, but the improvement would not *necessarily* be permanent. For this single jetty to produce twelve feet, the estimate was $432,980.

BEGUN MAY, 1880.

1880. In May, 1880, work was begun on the single jetty extending from Mustang Island. A storm in August of the same year destroyed a large part of the work.

1883. In 1883, the citizens of Rockport and Corpus Christi subscribed

$10,000 to continue the contract, and with other moneys appropriated by Congress, work was continued until April, 1885, when it was suspended. The jetty was then 5,500 feet long, of which 1500 feet was on shore. Of the remainder, 3,300 feet was built up to ordinary high water at the inner end, while the outer portion was from three to fourteen feet below water and crossed the channel. No north jetty was built. The cost to July, 1887, was $393,556.95.

1887. "In view of the injury sustained by the works and the lack of results, a new survey was made in March, 1887, under the direction of Major Ernst, U. S. E." He reported that "The single jetty had but an insignificant effect, giving only eight and a-half feet depth, and that the channel was across the jetty, which was in a dilapidated condition." He submitted a new project to secure twenty feet by parallel jetties, 2000 feet apart, estimated to cost $1,688,500, and added "The original estimated cost of this work, as here revised, is $2,052,543.72."

1888. The next Report, 1888, page 1314, states also that "the curved "portion of the jetty has practically disappeared," etc. "The effect of the work upon the bar has been insignificant."* The revetment of the head of Mustang Island was however continued until May, 1889, when work at the Pass was suspended.

1889. The Board appointed, March 2, 1889, recommended the concentration of expenditures upon the work at Galveston, but stated that the Harbors of Sabine and Aransas Pass were worthy of great consideration. Work ended May, 1889.

PRIVATE WORK RESUMED.

The Aransas Pass Harbor Company was incorporated March 22, 1890, and the Government relinquished the work June 30, 1890, after expending $550,416.58. The estimated value of the work in place was

For the "old jetty from shore to wreck of Mary"	$68,400.00
And for the revetment of Mustang Island	163,307.41
	$231,707.41

From which it would appear that there was none of the jetty remaining beyond the wreck of the "Mary." The Company was to secure twenty feet of water by 1899 under the State grants and the franchises granted by Congress. These have been twice extended, to January 21 of the same year.

On November 22, 1897, a Board of U. S. Engineers reported that the Company had exhausted its resources and had suspended work on the bar "without obtaining a greater navigable depth than 8.5 feet." Yet the chart showed 9¼ feet and great reduction in the size of the bar. The Company's first efforts consisted of a jetty built on the *south* (or wrong) side of the channel in 1892, composed of wooden cylinders, seven feet in diameter, sunk vertically by the water jet and filled with sand, but this not proving

*In 1891, the U. S. Coast Survey plans showed only seven and one-fourth feet on the bar.

sufficient after several years of labor, during a period of great depression, the Company was reorganized upon a basis of a land bonus of $400,000 and the reaction breakwater, as planned by Prof. Haupt, was introduced.

Instead, however, of entering into a contract for the entire work as designed, the Company was only willing to construct about half of the necessary breakwater and entered into a contract, on July 3, 1895, with Charles Clarke & Co., of Galveston, for the sum of $145,000 to complete this portion of the breakwater.

Work was commenced in August, 1895 and prosecuted so rapidly that by November of the same year *(less than three months)* the remains of the curved portion of the old Government jetty, built across the channel prior to 1885, and reported to have disappeared in 1888, were discovered in place, *covered with rocks at depths of from 11 to 13 feet.* This obstruction prevented further scour, making it impracticable to secure the predicted fifteen feet, until its removal, which was strenuously urged by the consulting engineers, but not executed by the Company. Instead, it extended the inner end of the breakwater and raised it to the surface, hoping thus more effectually to control the ebb currents, which were powerless to scour out this rock-covered sill.

1896. In this emergency, Col. C. P. Goodyear, of Brunswick, Ga., made a proposition to remove the obstructing Government jetty, and complete the entire breakwater for a lump sum, conditioned on results, and on September 12th, 1896, the contract with him was executed. The contractor exploded some 13,000 pounds of dynamite on the jetty, making a breach several hundred feet in length, and thus detaching the outer portion, although not removing it from the channel, but in consequence of his inability to obtain the funds from the Government for the results believed to have been secured at Brunswick, Ga., in time, he was obliged to suspend operations at Aransas, at considerable loss, in the Spring of 1897.

The breach made by Col. Goodyear, however, enabled the currents to pass through the outer portion of the bar and to continue their work, though enfeebled by the submerged jetty so that notwithstanding the prevalence of the strong South-east winds, driving large quantities of sand northwardly during the summer months, there was thereafter reported a progressive improvement in the depths over the bar, with the breakwater incomplete and the currents not then under adequate control.

1898. An examination of the bar, made on August 2, 1898, by competent engineers and sailing masters, revealed more water than had ever been reported for this location, and showed a remarkably well defined, fixed channel readily navigable for sailing vessels. This, too, notwithstanding the fact that no work had been done for over a year and that the season was very adverse to the maintenance of a good channel. The partial breakwater had built its natural counterpart of sand, solely by the action of the currents, sweeping out and reacting on the concave face of the structure, which does not appear to have settled after these several years of exposure.

Concerning the results secured up to that date it was reported by a resident of the Pass as follows:

"Having been stationed at the Aransas Pass Inlet since 1886, and being familiar with the depths of water on the bar, it gives me pleasure to say that since work was stopped on the unfinished breakwater, in 1897, there has been a continuous deepening and improvement in the channel, which is at present deeper than I have ever known it to be. This at a time of year when the South-east winds usually cause shoaling, but the currents now partly under control are able to maintain the channel they have created."

On the completion of the first contract, the Resident Engineer in charge reported to the Harbor Company the following results:

"The results which have been attained by the construction of this breakwater are satisfactory and marked to a degree. Considering the fact that the deep water lines are drawing closer together, the distance from twenty feet depth of water in the Gulf to twenty feet depth inside the bar being 3,500 feet, against 6,200 feet at the start, whilst the fifteen and twelve feet lines have made more material advance and the depth of water, the bar having deepened permanently three feet in a short space of time, there should be no reason to doubt that as soon as the currents have been controlled by the completion of the entire breakwater the anticipated results will be forthcoming." . . . .

"When the breakwater shall have been built up to its full height and length as proposed by the Consulting Engineers, there can be no question that the channel will deepen rapidly and permanent deep water secured. The sands carried by the flood tide will then be intercepted and the ebb discharge will be concentrated and restricted in its escape through the channel.

"The portion of the breakwater already built has had the effect of intercepting the sands of the flood tide, as the water is now shoaling north and east of this breakwater and the conditions of equilibrium of the flood and ebb currents are perceptibly changed."

Further, on the 11th day of February, 1899, Captain Welker, in command of the U. S. Coast Survey Steamer *"Bache,"* engaged in making a complete survey of the Pass, wired the office, that there was a clear channel depth of *fifteen* feet entirely through. This was followed by a letter reporting that the weather conditions were so bad as to prevent surveys on the bay more than about one day out of each week. In his official report he also states:

"In 1895, the Aransas Pass Harbor Company constructed a jetty in the shape of the letter "S," on the north side of the entrance, which is still in existence, and ever since its construction there has been a marked increase in the depth of water on the bar. The present channel crossed the Mansfield Jetty, portions of which are still in position. An attempt was made to remove this by explosion of dynamite, with the result that the rocks scattered over considerable area and without doubt they prevented the current from scouring the bottom to its full capacity.

"It is my opinion that, by the completion of the present jetty and the clearing away of the rock in the entrance a channel of at least twenty feet in depth would soon be secured."

On the other hand the Board of U. S. Engineers, in reporting on this work shortly after the suspension of the Goodyear contract, said:

"It was thought by the Company's engineers that the old Government jetty acted as a dam to prevent further deepening. This jetty was therefore blasted out over a length of about 500 feet. This blasting was followed by an advance of the inside contours." . . .

"There does not seem any probability that the jetty, as now constructed, will of itself secure and maintain any considerable increase of depth in a navigable channel of proper width."

Notwithstanding this guarded prediction the Welker report shows a progressive deepening from the eight and a-half feet, said to be the least depth, to fifteen feet, in a little more than a year with no additional work done at the site—and the latest reports, after the plan is said to have been completed (in 1906), are that the depths reach to from eighteen to over twenty feet entirely across the bar, which it is now proposed to destroy by a return to the original project of 1887, as recommended by the Board of U. S. Engineers for the purpose of maintaining a channel which is already *self-created* and readily navigable.

APPENDIX "B."

COPY OF OPINION OF JUDGE ADVOCATE GENERAL

As based upon the communication of the Chief of Engineers as to the appropriation made for the express purpose of removing the old Government jetty obstructing the channel scour at Aransas Pass, Texas. It reads:

December 17, 1900.

"Respectfully returned to the Secretary of War,

The River and Harbor Act of Mar. 3, 1899, contains the following item:

"Improving Aransas Pass, Texas. For dredging and other improvements of Aransas Pass Harbor, sixty thousand dollars; Provided, that the Secretary of War is hereby authorized to contract for the removal of that portion of the old Government jetty in said harbor from the end nearest to the curved jetty constructed by the Aransas Pass Harbor Company to the wreck Mary, in such manner as to in no wise interfere with the curved jetty now located in said harbor; And provided further, that said contract shall not be let by the Secretary of War, nor said work done, until the said Aransas Pass Harbor Company shall have properly released and surrendered all rights and privileges heretofore granted to it in said harbor by Congress, also the jetty constructed in said harbor." (30th Stats. 1128.)

In 4th endorsement hereon the Chief of Engineers says:

"The requirement as to removal of old Government jetty was introduced in the item by Congress and in accordance with the requirement a contract was entered into in January last, with Charles Clark & Co., but in the opinion of the Engineer officer in local charge of the work it would be to the interest of the work to postpone removal of the Government jetty as contemplated by the act and contract made in accordance therewith

until other and more important work had been accomplished. The District Engineer officer, Captain Riche, recommends that, instead of removing the old jetty at this time, the available funds be applied to repairs to what is known as the "curved jetty," and to dredging, surveys and contingencies, etc. He proposes to annul the present contract for removing the old jetty, no work having been done under it and the contractor being willing, and to make, without advertising, a new contract amounting approximately to $75,000 in its stead, on terms considered by him very reasonable and advantageous, covering the work of jetty repair and construction considered essential at this time."

The matter has been referred to this office for opinion.

"1. Whether in view of the language of the act the removal of the old jetty can be postponed, and the money appropriated be applied to the work of jetty repair and construction proposed by Captain Riche."

"2. Whether it would be legal to abandon the present contract, by mutual consent, and substitute therefor a new contract with the same parties, covering the new work, without inviting competition by public advertisement."

"In my opinion the act is not to be construed as requiring the removal of the portion of the old Government jetty specified therein, but as authorizing its removal. An appropriation of sixty thousand dollars is made generally "for dredging and other improvements of Aransas Pass Harbor," and this is followed by the provisions that "the Secretary of War is hereby authorized to contract" for the removal of the portion of the jetty referred to. There appears to be nothing in the act which limits the expenditure of the appropriation, or any portion of it, to the removal of this jetty; and I am of opinion that the entire appropriation can be expended for other improvements. No objection is seen therefore to a supplemental contract with Charles Clark & Co. providing for the termination of the existing contract for the removal of the jetty, provided such action is deemed for the best interests of the United States."

As to the second point it was ruled that it could not be legally done without public advertisement.

The case as presented makes the opinion of the District Engineer superior to the decision of Congress as to the necessity of removing the obstruction which the Government itself had previously placed across the channel and which it persistently declared was not acting as an obstacle, even after a survey involving over 500 borings showing rock in place at depths of from eight to thirteen feet, had been made but not published.

It is a fact that the River and Harbor Committee in executive session called the writer before it and asked him what the cost of the removal of that obstacle would be, stating that it was the desire of the Committee to make a test of this method, and if the prediction of fifteen feet resulted from this part of the work, after the removal of the obstacle, then Congress would complete the work upon this plan, but that the whole matter was contingent upon the taking up of this obstacle. It was stated to the Committee that it could be done for $50,000, and the Committee made it

$60,000 to cover any possible contingency, and voluntarily inserted the proviso that the curved jetty in said harbor should in no wise be interfered with, so that the work might be conducted strictly in accordance with the design of the inventor.

The authority to apply the money to the jetty, conferred by the official opinion upon the allegation that more important work of "repairs" was required, and the release of the contractor after a delay of more than a year of inactivity, and the execution of a contract with him to build up the *inner* end of the jetty first, in violation of the proper method of procedure and while the old jetty still remained to obstruct the passage of the currents seaward, resulted in great injury to the channel by rolling the bar forward and creating a shoal by subsequently leaving a breach of about 1600 feet in the center of the work, for several years, thus enabling the currents to escape and the drift to enter the channel, still further delaying results.

All this was the sequence of the failure to execute the provisions of the act of 1899 in accordance with the expressly stated purpose of Congress. The old Government jetty was not removed until 1904, and even then a rocky lump remained with less than seventeen feet depth, which was only taken out in 1906, thus finally, after many years of delay, enabling the currents to operate freely upon the channel. The results which have followed, notwithstanding these most serious delays and unusual obstructions, have no precedent in the annals of harbor improvements in the world, either as to economy or results, yet it is now proposed to obliterate them by the immediate return to the original two-jetty plan of the Government, before the unaided currents of this feeble tidal inlet have had sufficient time to establish a permanent regimen, as agreed upon when the plan was taken over by Congress.

L. M. HAUPT.

APPENDIX "C."

MEMORIAL AND BRIEF SUBMITTED TO COMMITTEE ON COMMERCE, U. S. SENATE, FEBRUARY, 1902.

Improving the Entrance to Aransas Pass, Texas, by Natural Methods.

COMPARATIVE SUMMARY OF RESULTS AND COST.

Prior efforts by Government and others. *No results.* Cost, $657,885. The "Haupt" plan, partially built by the Aransas Pass Harbor Co., *increased depth nine feet.* Cost, $235,000. Cost, per foot of depth gained, $26,111, which is unprecedented.

COMPARATIVE PROPOSITIONS.

The Government proposes to build *two jetties and dredge* a twenty-foot channel, which *will not be self-maintaining;* without guarantees or time limi-

tations; with no risks as to results and with no probability of continuous appropriations to complete for $1,526,000.

Prof. Haupt, if given the contract, proposes to complete his curved breakwater, now embodied in the Government plan; guarantees the channel and its maintenance by tidal scour for two years, surrenders all rights under his patents at Aransas Pass, and gives bonds for the faithful performance of his contract, for the sum of $500,000, *thus saving at least $1,025,000* in case the plan succeeds; but should the channel not be secured, he forfeits the final payment of $100,000, or should it not prove to be self-maintaining for two years, $75,000 more, thus reducing the cost of the breakwater in place to $325,000, all of which work is embodied in the Government plan, so that *it would lose nothing*. The bond of $50,000 is given to protect the Government from any damages for failure to fulfil conditions of contract.

EQUITIES.

The inventor of this plan has a deep professional interest in the proper conduct of the work; his bill safeguards the Government fully and he proposes to prosecute the plan vigorously to completion. On the other hand, if these plans are relegated to unfriendly parties to be executed, it will cost more, take longer to finish, will not release the Government from claims for infringement of patent rights, and may be entirely defeated by an improper order of construction or failure to remove the obstructing jetty.

The work has already been under the Government control for about three years, with an appropriation specifically made for the removal of the old jetty, which has not been done.

THE VALUE OF THE WORK.

The Report of the Board of Engineers, dated November 22d, 1897, states:

"The value to the Government of the works of the Aransas Pass Harbor Company for the improvement of Aransas Pass, Texas, is nothing."

Up to the date of the abandonment of this Pass by the Government, in May, 1889, it had expended $550,416.58 without material improvement, while the Harbor Company subsequently expended $235,000 on the north jetty, which at the date of the report had deepened the channel from 6½ to 9¼ feet,* and it has since continued to deepen without assistance or further work, to 15½ feet, at which depth the channel is held by the remains of the old, rock-covered jetty, built by the Government and reported as having "disappeared."

The Government's revised estimate for securing twenty feet by two jetties and dredging in 1889 (vide reports of Chief of Engineers) was $2,054,343.72, and in 1898 (Doc. 119, H. R., 55th Cong., 3rd Ses.) it was

*Document 137, H. R., 55th Cong., 2nd Session.

$1,525,000.00, showing a reduction of $529,543.82 due to the results secured by the works of the Harbor Company, which were reported to be of no value.

Prof. Haupt, the inventor of the curved breakwater which has produced these unprecedented results, has proposed to Congress to complete his work and to guarantee the channel for $500,000, thus saving the further sum of $1,025,000, and he further agrees to maintain the channel for two years by tidal scour without charge, or forfeit $75,000 as a demonstration of the great value of the device, even under such adverse circumstances. He further surrenders all claims for royalties at Aransas Pass in case he is permitted to complete his breakwater at that place.

PHYSICAL RESULTS OF THE WORK.

This report also states that in the opinion of the Board,—

"There does not seem any probability that the jetty as now constructed will of itself secure and maintain any considerable increase of depth in a navigable channel of proper width."

(Vide Page 15, Document 137, H. R. 55th Cong., 2nd session.)

On the contrary, the results have shown how little the operations of the curved jetty were understood by the Board, since this incomplete structure, without any additions or aid from dredging, has caused the removal by scour of over half a million cubic yards of material, has increased the depth of the channel nine feet, at the shoalest point, has maintained and fixed the channel in position and has deteriorated less than most jetties, notwithstanding its incomplete condition, both as to length and capping. It has not been undermined nor is there even a trough near its base, while the maximum depth shown* was 25¼ feet.

All this without cost to the Government, since this is the result of the work done by private parties and turned over to the Government three years ago on condition of its being completed at once.

This progressive deepening, widening and maintenance is now arrested by the presence of the old Government jetty. Such a result is believed to be unparalleled in the annals of harbor improvements, and it has been crowned by the highest premiums from learned societies.

THE OBSTRUCTING "OLD GOVERNMENT JETTY."

This jetty was built between February, 1881, and April, 1885. In the Report of the Chief of Engineers for 1882, page 1314, it is said: "The work designed to deepen the channel over the bar was a jetty on the south side of the entrance. It was constructed upon a line running east and west to a point 2,352 feet from the shore, where it curved northward upon a radius of 2,880 feet and extended 1,698 feet further, making a length from shore of 4,050 feet.

* * * * * * *

*Vide official survey of 1900.

It was constructed of superposed mattresses ballasted with stones. . . It appears that the curved portion of the jetty has practically disappeared. Of the straight portion . . . that which was built out into the Gulf has its crest, upon an average, about three feet below mean low tide. . . . Its height above the bottom has diminished about 6.2 feet, or over 50 per cent. . . . The effect of the work upon the bar has been insignificant."

The expenditure for this experience was $393,556.95 to July, 1887.

As the work of the Harbor Company proceeded, the current scour soon revealed the existence of this obstructing jetty lying across the entire channel so that it limited the depth, and as it was not anticipated, due to the report quoted above, no contract had been made for its removal.

When the work was returned to the Government, in 1899, it immediately appropriated $60,000 for the removal of the old jetty "in such manner as to in no wise interfere with the curved jetty now located in said harbor."

A contract was let in accordance with the terms of this act, but no work was done and after thirteen months had elapsed it was annulled.

A careful survey with borings was made of the old jetty, and upon it the opinion was expressed that "It was not acting as an obstruction." (See Report, Chief of Engineers for 1901, page 1952.) The drawing was "not printed" but it shows very clearly that this old jetty is still in place, covered with rock extending entirely across the channel at depths of from 11 to 15½ feet. It is therefore an absolute barrier to the creation of the proposed twenty-foot channel or to the further deepening of the present improved one, and yet, in consequence of these representations, authority was obtained to permit it to remain and to apply the money appropriated for its removal to the part of the jetty which was not to be interfered with under the law, with the result that the work now under contract is causing shoaling and bar advance, so long as the jetty remains and the outer end of the breakwater is incomplete.

Thus all efforts to secure the removal of this serious obstacle to the creation of the channel by scour have been thwarted, and it remains a barrier to commerce as well as a bar to the demonstration of the complete practicability of the reaction breakwater.

OTHER BARRIERS.

In a recent communication* to the Chairman of the Rivers and Harbors Committee, from the office of the Chief of Engineers, occurred these statements:—

"The Government jetty contemplates an apron of stone along entire length of jetty, eighteen feet wide, three feet thick, which is not a part of the Haupt plan, and requires about 17,000 tons of stone."

A reference to the original plans of the Haupt jetty, as published in the official report, Doc. 137, would have avoided this error, as the apron of the full dimensions is there shown as it was built and from which that in the

*Without date or signature.

Government plan is copied. (See same document.) It is also stated that, "The Government plan contemplates a sill from the end of jetty to shore, etc."

If this sill is built, it will defeat the purpose of the breakwater by cutting off a large portion of the only force available for scour, and ultimately require a second jetty and dredge to secure and maintain the channel, so that it would be a fatal mistake, as there is no injury to the physical conditions by leaving it open for the free admission of the tides. This is fundamental to success.

ARGUMENT AGAINST HAUPT'S PLAN BY THE ENGINEERS.

Again it is stated: "The Haupt jetty on Government plan will cost $575,000, including sill and apron."

Such sill and apron are estimated to cost $94,250 by the engineers at an assumed unit price, which is less than the present contract price. The letter is a criticism of Haupt's bill for deepening channel at Aransas Pass, and this statement is a comparison of cost of work under his bill and work if left in the hands of engineers.

It seeks to show that there is no "apron" in Haupt's plan, which is erroneous; also, that a "sill" is needed. Although a sill is no part of Haupt's design, and would defeat its purpose, and that if the cost of sill and apron, $94,250, is deducted from their estimate with sill and apron, they will do as much with $480,750 as Haupt with $500,000.

This is in no sense a fair comparison. For they say Haupt's Breakwater will not get the twenty-foot channel and offer a plan at a cost of $1,525,000, which they say will get the water by aid of dredging. Haupt says his device will get such channel, and maintain it without artificial aid for two years at a total cost of $500,000, and agrees to forfeit $75,000 if it is not thus maintained. He also forfeits last $100,000 to be paid for breakwater if full twenty feet, 150 feet wide is not procured. He is paid, therefore, for *merely* building of breakwater, but $325,000, which would be their basis of comparison with their estimate of $480,750, without sill or apron, assuming, as they do, that neither Haupt's nor their construction of breakwater, unaided, will get the water.

The comparison, however, should be between their estimate of $1,554,423.72, which they say *should* get the water by dredging and jetties, and Haupt's $500,000, which he believes, as shown by local physical condition, *will!* get the water, and any other basis can have but one effect, namely, to cloud the real issues.

To be entirely fair, comparison should be stated thus:—

Expended by U. S. Engineers, without result, up to 1890 (on twelve-foot project)	$ 550,416.58
Their revised estimate for twenty feet	2,052,543.72
	$2,602,960.30

Spent by A. P. H. Co on north jetty (gain, depth nine feet)	$235,000.00	
Bid by Prof. Haupt to complete	500,000.00	
		735,000.00
Difference saved had Haupt plan been available from the start		$1,867,960.30

Brief of L. M. Haupt and Associates to Improve Aransas Pass, Texas, for $500,000, which is less than One-third of the Estimated Cost by the Government Plan.

The proposal is to create a channel and to maintain it for two years by the natural scour from the tides, having a width of 150 feet bottom, and a depth of twenty feet over this width, entirely across the bar, by means of a single curved or Reaction Breakwater of stone, of sufficient dimensions to control the currents but not oppose too great superficial resistance to waves, for the sum of $500,000.

The work is to begin within three months and the channel is to be secured within three years or he shall forfeit $175,000 of the above amount, and he shall also file a bond of $50,000 for the faithful performance of the contract.

The work shall be done under the Secretary of War and the payments be duly certified by an experienced Government official in his department, to be designated by him.

In consideration of this contract, the said Haupt shall surrender all his patent rights to this improvement at Aransas Pass and make no claim for its use or for damages. He shall further remove the obstructing old Government jetty and complete the breakwater as designed for the Aransas Pass Harbor Company in 1895.

He shall take all risks, and in case of failure to commence or to continue the work as specified, he shall forfeit it and his penalties without delay and the work shall be continued by the Government.

The Rivers and Harbors Committee being unanimously in favor of completing the Haupt plan, proposes the following item:

"Improving Aransas Pass, Texas.

"Continuing improvement, two hundred and fifty thousand dollars: *Provided*, That the work at this harbor shall be confined to the completion of the north jetty in accordance with the design and specifications of the Aransas Pass Harbor Company, and in continuation of the work heretofore carried out on said jetty by said company, and to such additional work as may be necessary for strengthening such part of the old Government jetty and any other hard material which may interfere with the formation of a channel by the natural action of the currents."

OBJECTIONS TO PRESENT FORM OF ITEM.

Under this provision of the House Bill the work is transferred to those who have persistently opposed it as of no value and who have predicted its failure, to be executed, with an amount not half large enough to complete, and with the probability that it may be expended in injuriously enlarging the dimensions without producing additional scour, with no responsibility for results and no limitations as to the time within which the work shall be commenced or completed. Neither is there any guarantee that the obstruction after Congress had directed its removal and made an appropriation therefor, will be sufficiently removed nor that the work will be prosecuted in such order as to produce scour instead of deposit, nor that the admission of the flood-tide upon which the scour depends will not be seriously restricted by the proposed sill embodied in the Government plan and constituting part of its north jetty, any or all of which would prove injurious if not disastrous to the Haupt plan and ultimately involve the further expenditure of more than $1,000,000 in a second jetty and for dredging and further sums for maintenance which are not provided for in this bill.

It is therefore proposed to request the Senate Committee on Commerce to accept Professor Haupt's proposition as being reasonable, safe, equitable and in the interest of the public service.

All of which fears have been fully confirmed by the subsequent expenditure, and the life of this patent has expired.

A PECULIAR WELL.

A member of the United States Geological Survey, engaged in making investigations of ground-water conditions in Ohio, reports that in Hamilton County, about half a mile south of New Burlington, there is a well which yields fresh and salt water at the same time. Except for the fact that two pumps are set in it side by side it resembles ordinary wells; but one of the pumps supplies water excellent to taste, while the water from the other is so highly charged with various mineral salts that it is almost brine. This water has been recommended by some physicians as having high medical value. When first dug, several years ago, the well was a great wonder to the people of the surrounding country, who flocked in great numbers to see it and taste its unusual water.

The secret of the phenomenon lies in the fact that two water-bearing beds confined between layers of limestone occur at this point, the upper carrying fresh water and the lower salt. The pipe of the fresh water pump is but sixteen feet long; that of the salt-water pump is thirty-five feet. The brine, being heavier than the fresh water, does not mix with it, but remains at the bottom of the well, and the longer pipe consequently draws only the salty water.

Section of Physics and Chemistry.

(Stated meeting held Thursday, November 21, 1907.)

The Corrosion of Steel.

By Allerton S. Cushman,

Assistant Director Office of Public Roads, United States Department of Agriculture.

Iron is unique among the elements, not only on account of the ease with which it dissolves or combines with nearly all other elements, but also on account of the changes in structure and physical character which are produced by the presence of almost infinitestimal quantities of impurities. A variation of a few tenths of one per cent. in the amount and condition of the carbon content may produce such a change in the physical properties of the metal, as to alter entirely its fitness for the various purposes to which it is put. A variation of a few hundredths of one per cent. of phosphorus in the specifications for certain useful forms of steel has been and still is a matter of controversy between interests representing hundreds of millions of dollars of capital and involving questions of the safeguarding of the lives and property of the public. Sulphur, silicon, and manganese are among the other well known elements whose presence or condition in extremely small amounts produces important differences in the character of steel. Absolutely pure iron has but a limited use in the industries of man, and as a rule the properties which are sought are produced by the presence of other elements.

This point is emphasized in order to call your attention to the fact that, chemically speaking, structural iron or steel is not a standard substance, but varies in composition and in character.

I have frequently called attention to the fact that resistance to corrosion was one of the most variable of the many characteristics of steel. That is to say, not only do the various kinds of merchantable iron and steel differ from each other within wide limits

in their resistance to corrosive influences, but specimens from the same mill or furnace will frequently show a great difference in this respect. There are few subjects at the present time more important to the engineer and the architect than the protection of structural steel from rapid, unsightly and dangerous corrosion. I wish to point out that there are two separate and distinct lines along which we may hope to make progress.

The first of these has to do with the understanding of the causes which promote corrosion and their elimination in the manufacture of the metal, and the second is the study of paint-films or waterproof coatings which shall really protect even the most inferior metals for indefinite periods. It is only the first phase of the subject that I shall consider to-night.

The tendency to oxidation is a characteristic inherent in iron, and an absolutely unrustable iron or steel will probably be impossible of accomplishment, even in the distant future. If, however, all the steel made resisted corrosion as well as the best of it, there would be no problem, and this paper would not have been written.

I shall not take your time this evening to review the older theories which were held to account for the rusting of iron, but will call your attention to the electrochemical or electrolytic explanation, which is now coming to be generally accepted. According to modern chemical theory, all reactions which take place in water solution are attended by certain readjustments of the electrical states of reacting particles which are called ions. You are undoubtedly aware that under the atomic theory molecules of compound substances are made up of atoms which are held together by a force or forces which represent large amounts of energy. Now, some substances, when they are dissolved in water, will conduct electricity, while others will not. The first class of substances which are generally inorganic acids, alkalies, and salts, we call electrolytes, while those organic bodies, such as sugar, which do not conduct electricity in solution, are non-electrolytes.

Arrhenius, a Swedish physicist, in 1887, announced the theory of electrolytic dissociation, the evidence for which can not be discussed here, but it can be said that the theory has been borne out by numerous researches, and is at the present time almost universally accepted. This theory tells us that the molecules of electro-

lytes, as they pass into solution in water, dissociate into ions which are simply atoms carrying, in spite of the smallness of their mass, very heavy charges of electricity. In order that no energy may be lost or gained, it follows that the dissociation must produce both positive and negative ions, which are equivalent and opposite. A rough analogy of what has taken place through dissociation is furnished by a coiled steel spring. If we put such a spring in tension and hold it thus, without addition or subtraction of material, we have impressed potential energy upon it, which will be returned in equivalent amount when by any means the tension is relieved. Indeed, we might consider one end of the spring as positive to the other end, and that in relieving the tension the energy reappeared by the neutralization of the positive and negative potentials.

To illustrate further what is meant by the theory of solutions, let us consider the system common salt and pure water. Common salt is composed of an atom of sodium combined with an atom of chlorine, and the molecule is represented by the simple chemical formula Na Cl. When sodium chloride is brought together with water it tends to go into solution, the molecules mingling with the molecules of the water, owing to a force known as solution pressure. As an increasing number of molecules appear in solution, however, a back pressure is exerted which to a constantly increasing extent resists the entrance of more molecules. This reverse action is known as osmotic pressure and it is perfectly clear that if an excess of salt is present the end of the action will come about for any definite temperature, just as soon as the osmotic pressure and the solution pressure are equal. But in addition to this the very important action takes place which has been just referred to. In passing into solution the salt dissociates into its constituent ions, which simply means that the solution forces tear apart the associated atoms and the energy which held them together appears in a potential form as equal and opposite charges of static electricity on the ions. So that the solution of salt in water is represented by the equation: $Na\ Cl \rightleftharpoons \overset{+}{Na} + \overset{-}{Cl}$, in which $\overset{+}{Na}$ and $\overset{-}{Cl}$ represent the constituent ions. Osmotic pressure, however, acts against the dissociation pressure just as it does against the solution pressure, so that in concentrated solutions

we have a reverse action also taking place represented by the equation: $\overset{+}{Na} + \overset{-}{Cl} \longrightarrow NaCl$.

Chemists therefore say that the state of equilibrium for the systen we are considering can be expressed by the reversible reaction:

$NaCl \rightleftharpoons \overset{+}{Na} + \overset{-}{Cl}$.

Now, bearing these simple details of the modern theory of solution in mind we may return to the consideration of the reactions which take place when iron rusts. If a bright strip of iron is immersed in a solution of a copper salt, such as the sulphate, iron goes into solution and copper plates out on the iron. The reason for this is that the solution pressure of the iron is greater than that of the copper ions, therefore iron passes into solution, the positive static charge being transferred from the copper ions to the iron ions. This reaction is simply written:

$$Fe + \overset{+}{Cu} \cdot \overset{-}{SO_4} = \overset{+}{Fe} \cdot SO_4 + Cu.$$

Now if we leave out the copper sulphate in this system, and immerse the strip of iron in plain water, a similar reaction takes place. It is known to chemists that even the purest water is to a slight extent dissociated, and therefore contains hydrogen ions. That is to say, while water consists mainly of molecules written H_2O, there also are present positive hydrogen ions $\overset{+}{H}$ and the equivalent negative hydroxyl ions $\overline{OH}$. Hydrogen acts as a metal and has a solution pressure somewhat less than that of iron. Therefore, when iron is by any means whatever brought into contact with water it will, to a certain extent, pass into solution by exchange with hydrogen. This reaction, upon which all forms of corrosion are primarily based, may be written:

$$Fe + 2\overset{+}{H} \cdot \overset{-}{OH} = \overset{++}{Fe} \cdot \overset{-}{OH} \cdot \overset{-}{OH} + 2H$$

It has been shown experimentally that iron can not at ordinary temperature combined with oxygen unless the iron first passes into solution and it is apparent from this that the initial cause of rusting is not oxygen, but hydrogen bearing a static electrical charge, in other words, the hydrogen ion. Now all acids derive their character from the fact that they dissociate in solution with the production of hydrogen ions, and this is the reason why all acids stimulate the corrosion of iron. On the other hand, alkalies disso-

ciate in solution with the production of hydroxyl ions, which by the reverse action already explained neutralize and remove the hydrogen ions and thus inhibit rusting.

It is well known to engineers that sulphurous acid, as well as carbonic acid, from coal smoke produces rapid destruction of steel, whereas alkaline cements, mortars, and concretes will preserve steel imbedded in them so long as the reaction remains sufficiently alkaline. The only cases recorded in which steel is said to have corroded when imbedded in concrete, are those where percolating water under pressure has washed away the free lime and thus removed the alkaline reaction.

We may now turn to the role played by oxygen in the rusting of iron. Iron is one of those elements which exists in more than one state of combination with oxygen. The least oxidized state is called ferrous, while the higher state is called ferric. Oxygen always changes ferrous to ferric compounds. Iron, having once appeared in solution in the ferrous condition by exchange with hydrogen, is at once attacked by oxygen and precipitated at the point of attack in the form of the insoluble hydrated ferric oxide which is known as rust. This statement is easily proved by experiment, for all solutions of ferrous salts are directly oxidized or rusted by standing in the air. The role of oxygen is therefore secondary, but it is none the less important for the simple reason that by precipitating the insoluble rust the iron ions are destroyed and removed from solution, thus lowering the osmotic pressure and making room for more to be formed. The scientific explanation would be that the appearance and precipitation of the solid phase (rust) lowers the osmotic pressure, thus enabling the iron, driven by its solution pressure, to pass rapidly into the ionized condition.

To sum up, then, as far as we have gone, the rusting of iron is caused, first, by the solution of the metal by exchange with hydrogen, and secondly, by the action of oxygen on the dissolved portion, both actions being accompanied by a transfer and neutralization of electric charges on the reacting atoms or ions.

The next important point is that the solution of the iron does not, as rusting proceeds, take place uniformly over the exposed surface, but on the contrary the solution is stimulated at certain nodes or points and inhibited at others. To this direct local elec-

trolysis is due the peculiar form of corrosion known as pitting, which is almost always observed when iron and steel are deeply rusted.

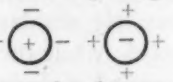
The fact that iron does not tend to go into solution uniformly and evenly all over the exposed surfaces, but passes rapidly into solution at certain surface points, can only be interpreted in one way; namely, that local electrolysis is taking place.

Now, applying what has already been said, it follows that as each iron ion appears in the solution a hydrogen ion must leave the system in order to maintain the equilibrium and so that no energy be lost or gained. It follows from this that hydroxyl ions must be left behind as the hydrogen changes into the gaseous form and disappears, so that we should expect to find a congregation of iron ions at one pole in the electric circuit and hydroxyl ions at the other. Owing to the formation, then, of these local electric couples, the surface should be protected at the negative poles around which the alkaline hydroxyl ions cluster, and attacked at the positive, where the iron is passing into solution, and being acted upon by oxygen.

Now,this action can be easily made visible as it takes place by means of a special indicator to which the writer has given the name ferroxyl. There is a certain reagent called potassium ferricyanide that forms a beautiful blue color, known as Turnbull's blue, when it comes into contact with ferrous ions. There is also an organic substance known as phenolphthalein which makes a rose-pink color with hydroxyl ions. Specimens of steel immersed in a solution of these mixed substances, and stiffened with agar agar jelly so that they cannot shake about, invariably show blue and red nodes, proving beyond all doubt the development of positive and negative nodes as corrosion proceeds.

Time will not allow of the presentation of a full discussion of the proofs that have been given to show that the corrosion of iron is always due to local electrolysis on the surface of the metal itself. The subject has been presented in detail in a bulletin recently issued by the Department of Agriculture. One of these demonstrations will, however, probably be of interest here.

When a section of rolled metal,such as sheet or plate,is immersed in water, if the electrolytic theory is correct, rusting must take place with the establishment of positive and negative spots or areas.

At the positive points iron will pass into solution and be rapidly oxidized to a loose, gummy, or so-called colloidal form of ferric hydroxide which is characteristic of rust formed under these conditions. It is a well known fact, as has been proved by experiment, that colloidal ferric hydroxide will move or migrate to the negative pole if subjected to electrolysis. We may therefore consider the possibility of two separate effects that may be produced, viz., when a positive center is surrounded by a negative area, and vice versa. These two conditions may be graphically represented by the two circles A and B: 

Now, as rusting proceeds we should expect in the case of A that the ferric hydroxide would be piled up in a crater formation, while the metal is eaten out at the center. In the case of B the effect would be reversed, and while the metal would be attacked in the surrounding area the hydroxide would be piled up in a cone at the center. That this is precisely what is taking place whenever a sheet of metal rusts under water a low-power microscope very clearly shows.

The photomicrographs in which the craters and cones are clearly shown have been published in the bulletin referred to above.

If you are willing to accept the electrolytic theory of corrosion you will very naturally inquire in what respect does it point the way to an improvement in the conditions as they exist at the present time. It follows from what has been said that the more carefully lack of homogeneity and bad segregation are guarded against during the processes of manufacture the less likely is the metal to suffer from rapid corrosion. If the iron contains metallic impurities dissolved in it, such as manganese, which differ electrochemically from iron, trouble is sure to ensue if there is a lack of homogeneity in the distribution of the impurity. In the old days when iron was made more slowly and received more careful working than is possible in the present day, serious corrosion was not the important problem it has since become.

The writer has in his possession a hand-forged nail, still in good condition, which was driven in the old Masonic Hall at Richmond, Virginia, in 1807, and for a long portion of

time has been freely exposed to the weather. There is a widespread opinion, which the writer shares, that the old wrought or puddled iron of thirty years ago is more resistant to corrosion than most of the modern steels.

But the interesting point is that modern steels vary so widely from each other. Here are two pieces of angle steel which constituted two members of a signal bridge on the Boston & Maine Railroad erected in 1894. These members were only six feet apart in the structure, and the conditions of environment, exposure and care were precisely similar, and yet one is corroded to the condition of lace work, while the other is hardly touched. The chemical and microscopical examinations of bright samples cut from these two specimens does not show any essential differences, both contain about 0.5 per cent. of manganese, and yet electrolysis has proceeded rapidly in one and almost not at all in the other. Does it not seem probable that the ingot, or portion of ingot, from which one of these members was rolled differed in segregation, or in chemical homogeneity, from the other? At all events, if all the members in this bridge structure had been as good as this best one, they would still be in service instead of on the table before you. It is of the utmost importance that we should learn to control the resistance to corrosion of structural steel, and to this end we should unite to urge upon manufacturers the necessity of making special efforts in this direction.

It would follow from the electrolytic theory that in order to have the highest resistance to corrosion a metal should either be as free as possible from certain impurities or should be by careful working and heat treatment rendered so homogeneous as not to retain localized positive and negative nodes for a long time without change.

Manganese is an element which is almost always associated in modern metallurgy with iron and steel, owing to the fact that this element is used as a flux in the great processes used to-day for changing cast iron into steel. Manganese, however, increases the electrical resistance of iron and as the percentage of this element, starting from zero, rises, the electrical resistance of the metal increases up to a certain specific maximum. Now, you will see, if the dissolving of manganese in iron raises the electrical resistance, that any changes in the equilibrium or distribution of the

manganese in the metal means that there will not be an even or homogeneous electrical conductivity throughout the mass.

If we have a metal in which the electrical conductivity for any reason varies from point to point on the surface we have the precise conditions which are necessary in order to establish the local nodes of electrolytic action on the surface which lead to rapid corrosion. It is apparent, therefore, that if we are to allow the presence in structural steel of comparatively high percentages of metallic impurities, such as manganese, we must attempt to obtain an extremely homogeneous distribution of such impurities. It is for this reason principally, in the opinion of the writer, that the more quickly and more carelessly the metal is manufactured and rolled, the more quickly it disintegrates under corrosive influences. As has been pointed out before, there are two methods of meeting the problem: first, to keep the percentage of metallic impurities as low as possible, and secondly, to guard against segregation and imperfect chemical homogeneity in the metal. In experiments we have made looking to the manufacture of a corrugated steel culvert for use in road building, it has been found by the author that corrugated metal, running as low as .04 manganese, has been more resistant to the corrosive test employed than the ordinary steel of the day, which usually carries about .5 per cent. manganese. Material of this kind has not been available for a sufficient length of time to determine whether under service conditions this low manganese metal will be longer lived, but it can safely be stated that the indications are all in its favor.

The writer has urged the manufacture of manganese-free steel for certain purposes, not because manganese is necessarily the cause of rapid corrosion, but because this impurity enables the metal to be rolled more easily and more cheaply, and in many cases permits the working in of large amounts of heterogeneous scrap. It is possible to manufacture shoddy steel as well as shoddy cloth, and though both of these materials have their legitimate uses for certain purposes, no one will claim for them high resistance to disintegrating influences. It is a hopeful sign of the times that manufacturers are beginning to pay serious attention to the manufacture of iron and steel for certain purposes which shall be to the highest possible degree rust proof.

Considerable attention has been given to the peculiarly passive

condition that can be induced on the surface of iron by contact with solutions of certain oxidizing agents. Without going into the details of this phenomenon, which have already been published, I will refer briefly to the peculiar action of chromic acid and its salts. Polished specimens of steel may be kept indefinitely without suffering corrosion when immersed in a dilute solution of potassium bichromate. On first thought it would seem a paradox that a strong oxidizing agent should have the effect of preventing the oxidation of iron, and yet this is the case.

According to the theory of the writer the oxidizing agent polarizes the surface of the iron to the condition of an oxygen electrode, so that it is immune from the attack of the hydrogen ions; thus the whole electrolytic process is checked or inhibited. A curious feature of this action is, that it is to a certain degree persistent after the metal has been removed from contact with the oxidizing solution, washed and wiped. This phase of the phenomenon requires further study, but at the present time it does not appear probable that the induced passive condition can be maintained on the surface to an extent that would make it of practical value for treating structural steel. With regard to the preservation of boiler tubes, and for certain special purposes it is not unlikely that a practical application of these principles will be found.

In conclusion it may be said that there is reason to hope that the time is not far distant when specifications may be drawn for material that is going into service under conditions which make it particularly subject to corrosive influences. The possible added cost of such specially resistant metal will be small in comparison to the benefits which will be derived from its use in the long run.

IN A NOVEL method of toughening metals lately introduced the metal to be treated is placed in a closed retort with a small quantity of mercury, says the London *Engineer*; the retort is subjected to pressure, and as it is heated to a point below melting temperature, a current of electricity is passed through the metal. Besides increased toughness, greater resistance to sea-water corrosion is imparted. The hardening is especially adapted for iron and steel, but is claimed to be useful for other metals.—*Eng. and Min. Jour.*

Mining and Metallurgical Section.

(Stated Meeting held Thursday, January 23, 1908.)

The Compression of Semi-Liquid Steel Ingots.

By N. Lilienberg.

The production of sound steel continues to be one of the most important questions of the present time. Previous efforts in that direction have mostly concerned special high-grade steel, but of late, even makers of structural steel and rails are looking for some suitable means of making ingots solid and of proper structure as well as of lessening the crop ends and segregation. In regard to rails, it has been conclusively demonstrated by experts (especially by the able engineer of the Philadelphia & Reading Railroad) that most of the failures in actual use, sometimes causing serious disasters, are due not to wrong chemical composition or of faulty heat treatment, but to treacherous cavities in the steel ingots, compressed by the rolling, but not welded. High authorities therefore now pronounce it very much to be recommended that even rail steel be compressed before the ingots are solid.

It is well known to be quite possible by any steel process to make sound steel without blow holes, the whole shrinkage then being taken up by the pipe which is correspondingly larger when other cavities are absent. In that case compression shows to greatest advantage, but even steel developing gases after being poured in the molds can be compressed solid, as I propose to show later on. It is only steel with surface blow holes which cannot be improved by compression.

The formation of pipe in steel ingots has recently been studied to considerable extent. Mr. Stead, in England, has published

very valuable observations, but it is especially Prof. H. Howe, in New York, who has gone deep into this matter. He shows that the formation of pipe is very complicated, because steel increases in volume at solidification and the sinking of the liquid steel then takes place at the different periods in accordance with the difference between swelling and shrinking of the interior and exterior. He has also by a series of experiments with melted stearic acid shown the influence of the temperature of the steel and of rapid and slow cooling on the formation of pipe.

I do not intend to discuss these matters here, as my object is to deal only with practical manipulation for improving steel. It is enough for practical work to know that pipe will more or less form in every steel ingot, no matter in what way it is cast. The advice to cast steel at certain desirable temperature is of course difficult to follow, besides this can never be completely executed, because the melted steel changes temperature between the casting of the first and the last ingots.

When steel has filled the mold there is instantly a thick crust of solid steel formed at the bottom and a thin crust on the sides enclosing a quantity of liquid steel. If the steel is allowed to cool undisturbed, the liquid mass inside gradually settles as solid steel in the inside of the shell, and as the quantity is not sufficient, owing to the contraction, a space is left extending from the top irregularly downward. If the ingot after being entirely solid and red hot is allowed to cool slowly without being worked, large crystals are formed, especially around the pipe, and there is danger that the internal strain may separate them and form fissures which afterwards may develop into large cracks.

This danger is again repeated when a cold unworked ingot is put into a heating furnace. An ingot allowed to cool slowly and undisturbed is made up of a surface of interlaced crystals and an interior of larger crystals of weaker cohesion. When, therefore, such an ingot, especially if it is of large size, is laid into a re heating furnace it is very difficult to prevent the surface from expanding more rapidly than the interior, which, therefore, is liable to break, sometimes with a perceptible sound. The cracks between the interior crystals are of course not visible, and there are cases when these have been enlarged by forging into considerable cavities, discovered when the finished article is machined, or still worse, not discovered until a break occurs.

It has been fully demonstrated that the steel crystals are larger in proportion to the length of time for solidification. Thereafter it depends on whether the substance binding the crystals together is strong enough to resist the internal strains during continued cooling. The whole steel industry may be characterized as "the struggle against crystals," and I therefore beg to emphasize the above said as being of equal importance with the obviation of pipe.

Segregation, depending on the floating upwards by the alloys of iron with lighter substances, can never be completely avoided but only lessened under special circumstances. These have been completely investigated by scientists, and it is not within the scope of the present paper to make a review of this matter. For practical purposes it is sufficient to remember that the longer the steel is kept liquid the greater opportunity is given for this separation to take place.

The defects to be overcome in steel ingots can thus be summed up as follows:

Coarse crystallinic structure in the interior.

Full sized pipe in sound steel.

Partial pipe and blow holes in steel where chemical action between carbon and ferrous oxide takes place in the molds.

Segregation.

A great deal of work and money has been spent on several methods for the purpose of preventing all this. Before discussing compression I consider it proper that other methods should be shortly reviewed, even if many of them are well known. I will therefore confine the observations to the work with the steel after it is poured in the molds, leaving out the phenomena in the melting furnace and ladle.

1. *Aluminum* thrown into molds acts on the upper part of the ingot, keeping it more evenly liquid, wherefore the diameter, but not the length, of the pipe, is lessened. It reduces ferrous oxide, thereby making the steel more quiet. But its action is confined to the upper part, and the lower is apt to have more cavities than otherwise. A larger quantity of aluminum is liable to be distributed in brittle spots all through the steel. The opinions as to the effect of aluminum on segregation seem to be divided.

2. *Casting continuous* ingots has been tried, but the practice has been largely abandoned. The apparatus is complicated, and as

the attachments to the cast ingots have to be removed, it can be used advantageously only for small ingots.

3. *Keeping the top uniformly hot* by placing a clay lined box on the top of the mold and applying a flame directed downward by blast through a coke fire is in successful operation, and a tolerably even sinking all over the section is thereby obtained. The apparatus is, however, complicated and must consume a considerable amount of coke, especially if a greater number of large sized ingots have to be treated simultaneously. The lining of the box will of course have to be kept at the melting point of the steel. When the operation stops the remaining liquid steel will continue to sink somewhat before solidification. The action can only extend to a limited depth, and thus cavities are liable to form in the lower pasty part of the steel. As the steel is kept liquid a longer time it is difficult to see how coarse crystals and segregation can be avoided .

4. *Casting with the large end upward.* The pipe is generally composed of one upper visible cavity ending with a thin bottom, below which another pipe stretches irregularly downwards to an undefined length with a point, or with a series of scattered cavities. This is the case in the ordinary tapered molds standing on loose bottoms with the small ends upwards. In casting with wide end upwards the pipe is generally confined to the upper visible sinking and the long stretched appendix under the bottom is absent, which is so far an advantage. This is now the prevailing method in Sweden. A clay lined box is placed on the top of the wide end of the mold, whereby the pipe is still further lessened. In most cases it does not stretch below the upper wide end of the ingot, which, however, cannot always be entirely relied on. Between the box and the mold the clay lining is so shaped as to create a neck in the steel which facilitates the subsequent striking off of the head. It is obvious that all casting with the wide end upwards tends to increase the formation of coarse crystals, but on the other hand the wider end receives more working in subsequent rolling. The method gives good results in Sweden, where high-priced steel is produced and where consequently the corresponding expenses can be borne. These consist in handling the molds by turning them upside down to get out the ingots, forming and drying the sink boxes, striking off and remelting the sink heads. If American manufacturers making medium-sized ingots

in stationary casting pit will bear the above-named expenses in making high-grade steel I offer my assistance in putting the process in operation, as I have recently personally witnessed its successful use in Sweden.

With a view of taking advantage of the shorter pipe when the wide end is turned upwards for such heavy ingots that it would be impracticable to turn the molds upside down after casting the following plan has been suggested. The small end is provided with a loose conical bottom, fitting closely into the recess. After solidification the mold is placed over a hydraulic ram, which forces bottom and ingot upward out of the molds, which is held down by two upright stationary bars shaped as hooks on the upper end.

5. *Centrifugal* force acts favorably in driving out blow holes, but can of course not obviate the pipe. Machines to that effect are, however, too unwieldy to come into general use. The molds will then have to be suspended on trunnions in the circumference of a horizontal revolving wheel. (In connection with this I beg to mention that I have built a machine for making hollow ingots by rotating the circular molds each separately in vertical position around its axle. The apparatus is more simple and the removal and replacing of molds easier than in previous attempts in that direction.)

I hope that this review has given sufficient reasons why the above named methods cannot come into general use for the largest quantities of heavy ingots, especially those which are cast standing on trucks. The only way to treat these is by *compression* of the *semi-liquid steel.* When properly executed such procedure will make the ingot free from interior blow holes and pipe, improve the structure by making the interior crystals smaller, thereby also lessening the subsequent work on the solid ingot, and reducing the segregation. To be effective the compression will, however, have to be timed according to the solidification. It must commence as soon as possible after casting and be continued as long as any liquid steel remains in the interior. If it commences too late the pipe has already been covered with oxide and is thus impossible to completely efface. If finished too early some liquid steel will remain and continue to form pipe. In several compression methods the inventors have lost view of these points. I have stated above that even steel developing gases in the mold can be compressed solid provided these gases do not appear close

to the sides. The following changes then take place. The first zone of occluded gases is closed up. Then a new quantity of gases in the liquid interior near the center is set free. If the compression stops there it has only moved the blow holes further inward, but if it is continued as long as liquid steel remains even this secondary blow holes will be closed up.

I have here below presented a review of the principal methods of compression which have been, or are tried in practical use.

1. *Compression from the top* has not gained any ground. It is obviously impossible to close up the pipe in that way, considering that the solid walls of the upper part of the ingot cannot well be compressed lengthways. Besides the gases are given no opportunity to escape.

2. *Compression from the bottom* is in successful operation at some works in France and England. The steel is then forced upwards into a conical mold, which the inventor compares to wire drawing, the top being left open. The bottom of the mold is of course loose and supported by a piston. The apparatus is here represented. The casting is done in a place separate from the press, and the ingots and molds are then transported together over a plunger which forces the loose bottom upwards together with the steel. The mold has of course to be strong enough, and is therefore preferably round or octagon, and it must be heavily banded. As the ingot gets firmly stuck in the mold another plunger from the top forces the ingot loose from the mold after the operation is finished. But this plunger is lifted up during the compression so as to leave the top open. This works well and economically when it comes to making a few large ingots, such as for heavy guns, shafting, etc. An apparatus of a similar principle is erected at a steel works in the country making heavy ingots for guns where the whole charge is emptied into the mold. Ingots made in this way are sound, free from cavities, of proper uniform structure, and the segregation is diminished. But if, for instance, a fifty-ton charge divided among twenty ingots shall be treated in this way the problem becomes complicated. As each ingot has to be pressed during a sufficiently long time it is obviously impossible to treat one ingot at the time in the same press, but a sufficient number of presses will have to be in operation simultaneously with correspondingly high expenses of installation. The attendance will also be expensive, as it is impossible

for one man to watch over the whole row of ingots, that they are worked properly. The molds will be very expensive and heavy to handle. It would be still more difficult to apply this system for the large quantities of steel cast on trucks.

3. *Compression from the side in the molds.* The constructions made on this principle must of course have divided molds. The two halves are separated by a short space as soon as a skin is formed sufficiently strong to hold the liquid interior during the compression. The results are quite satisfactory as far as improvement of the ingot is concerned. The following two constructions of this kind are worthy of mention:

(A.) The casting is done while the two halves of the mold are kept together by a hydraulic ram. When the solid skin of the ingot is strong enough the mold is opened sufficiently for introduced a plate as long as the ingot, after which the halves are forced together again by hydraulic pressure. The liquid interior is thereby forced to keep the mold filled to the top until the ingot is solid. By making the plate in section as a segment of a circle the sides of the ingot are not compressed. Such machines give good results, but can only be used for small sized ingots.

(B.) For heavier ingots the following construction is made: The halves of the molds are separated by two bars cross shaped in section and held together by a hydraulic ram during the casting. As soon as a skin sufficiently thick is formed the cross shaped bars are drawn up leaving the empty space between the edges of the molds. The hydraulic ram then slowly forces the molds together, thus giving the necessary pressure. This procedure gives very good results and is in continued practical operation. It can also be used for treating ingots standing on trucks. The obstacle in the way of a general adoption of this method are, however, that the molds of the steel makers will have to be changed from the ordinary solid tapered ones to straight divided.

That the handling of the divided molds is expensive.

That the walls will have to be made extra strong at the base if they shall stand the swelling of the steel during compression thereby making the molds heavy and expensive.

That the expense is further increased by the edges having to be planed.

That it is difficult to avoid a fin where the skin folds in the

space between the edges (which fins are planed off by a machine on the cold ingots, a procedure obviously unsuitable for a large and rapid production).

4. *Compression from the side on the bare ingots stripped of the molds.* In this way many of the above-named difficulties are avoided, besides the molds will last longer as not being in contact so long with the hot steel and liable to be pressed out of shape. The first question is whether it is possible to strip the ingots early enough. The time of solidification stands in proportion to the weight and size of the ingot. An 18″ square ingot weighing about 2 1/2 tons will require about one hour to get solid to the center. The stripping of such ingots usually takes place about thirty minutes after casting. Although this is somewhat late, liquid compression can still be done at that time, but it is preferable to reduce this to fifteen minutes. Experience has shown that this can be done at steel works, where the casting and stripping is managed properly. The taper of the molds should of course be sufficient and the inside of them smooth. One single small cavity, crack, or remaining scrap of steel may prevent the mold from slipping off the ingot. It is also desirable for early stripping that the stopper in the stripping machine is square instead of as usual, round, so as to enable it to get supported by the solid crust of the ingot while the usual round stopper is liable to sink down. It is even doubtful whether a stripping machine is beneficial for the ingots. The surface is so weak that it does not require much pulling force to produce surface cracks if the ingot sticks to the mold. It is therefore preferable for early stripping to have such a taper on the molds and so smooth inside surface that the molds can be lifted off by the ordinary travelling crane, especially as the work can then be made more rapidly by lifting several molds at the time. Ingots with a thin solid crust and liquid inside can obviously not be handled very much on account of the danger of the surface breaking.

The methods proposed of compressed early stripped steel ingots are mainly the three following ones: (A) *Rolling* the ingot in vertical position between four slowly revolving rollers. This would be theoretically the ideal compression, but it is very difficult to carry out for the reasons, *that* the ingots get out of shape between the rollers; *that* they cannot be easily grasped and handled in semi-liquid state; *that* the machine is not only complicated, but

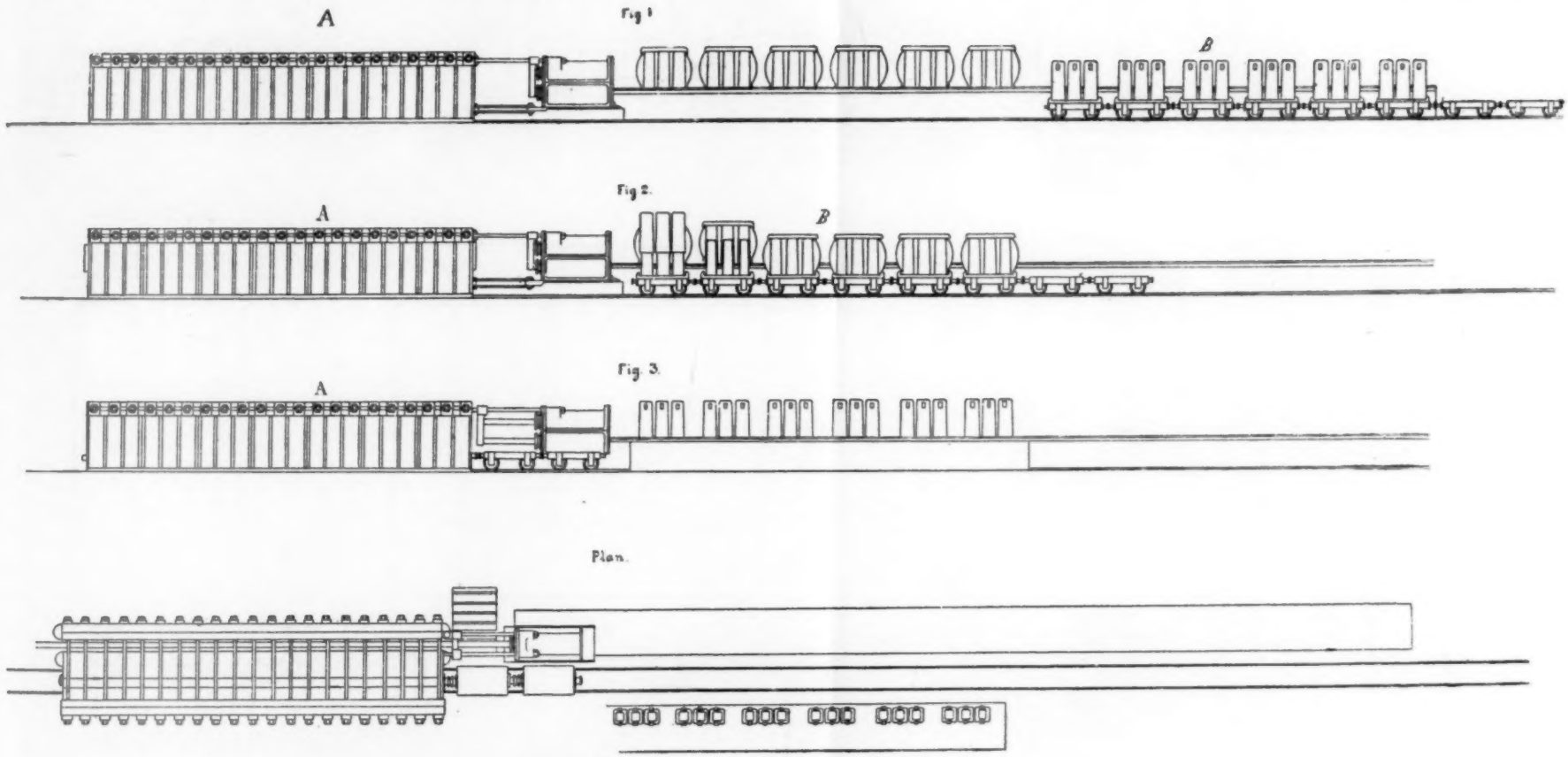


PLATE 1. Continuous press for steel ingots cast on cars.

Fig. 1

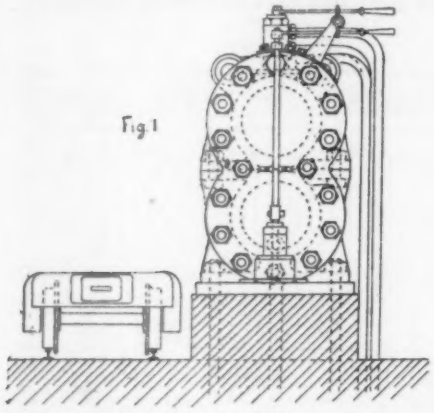


Fig. 2

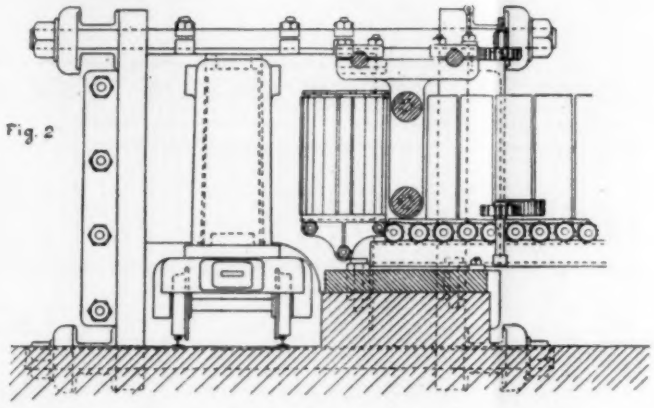


Fig. 3

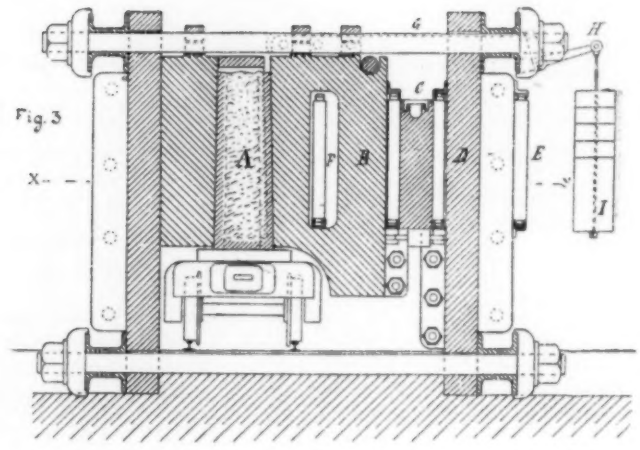
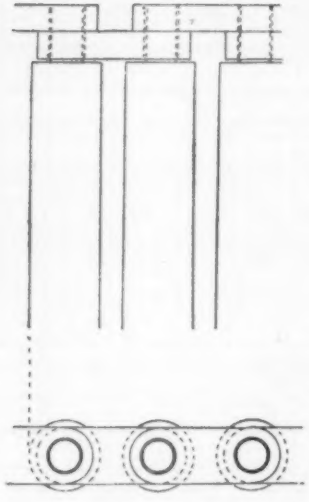
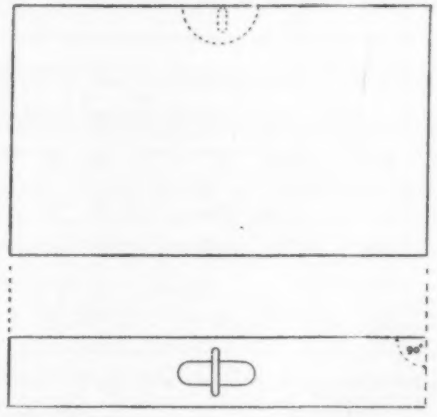


Fig. 4.





X–Y

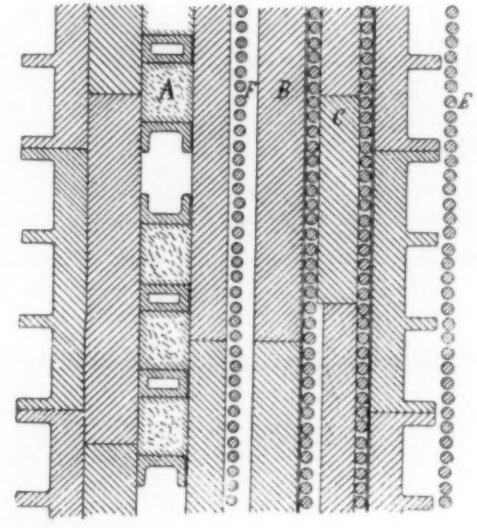
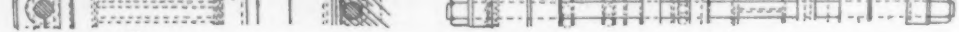


PLATE 2. Continuous press for steel ingots cast on cars.



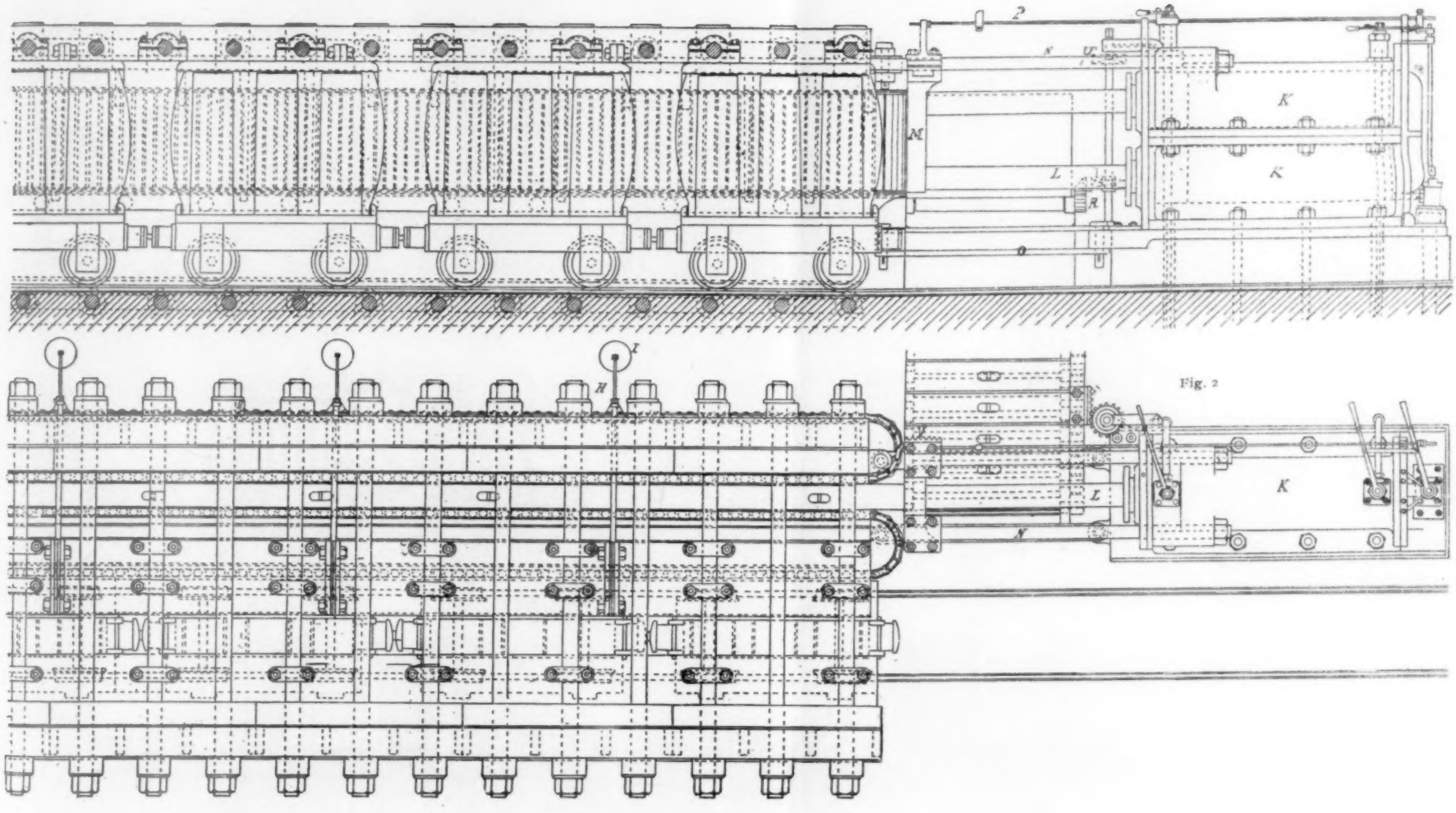


PLATE 3. Continuous press for steel ingots cast on cars.

Fig 1.

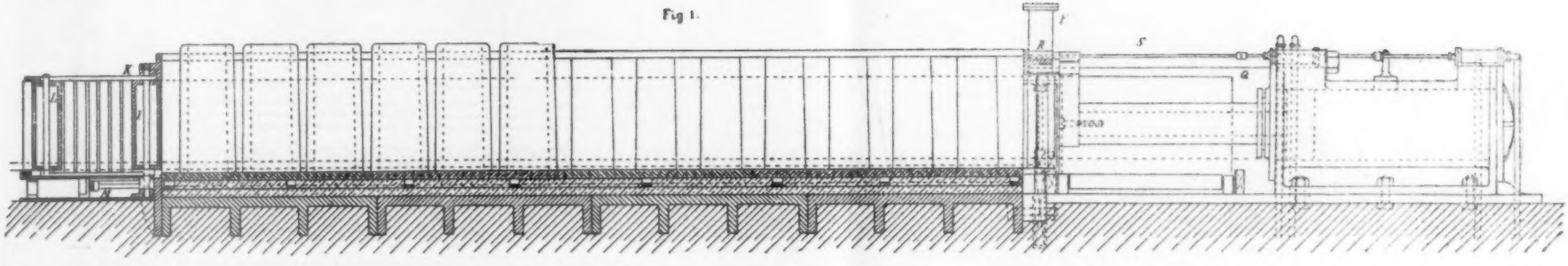


Fig 2.

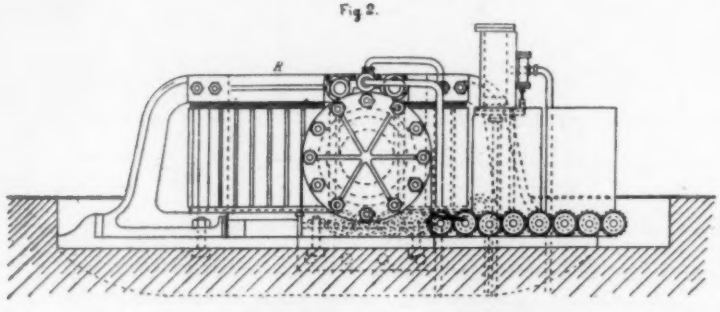


Fig 3.

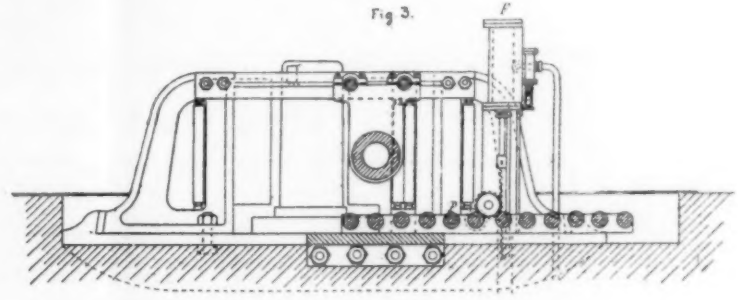


Fig 4

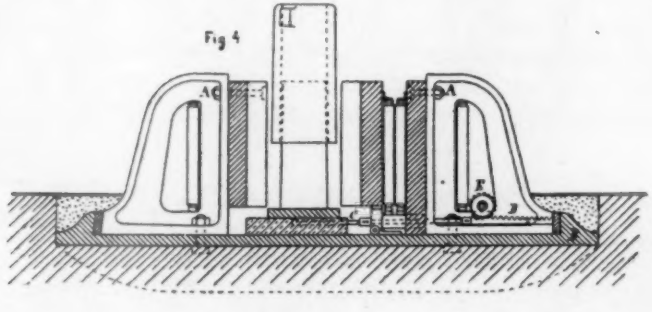


Fig 5.

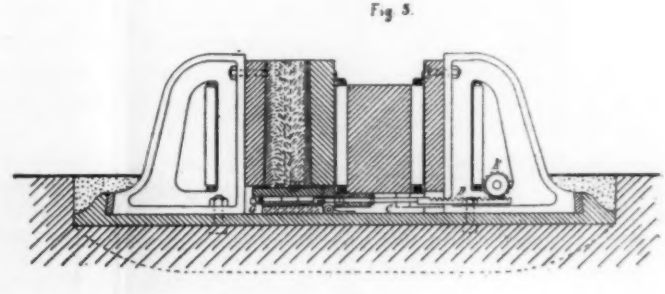


PLATE 4. Continuous press for steel ingots cast in pit.

Fig. 1

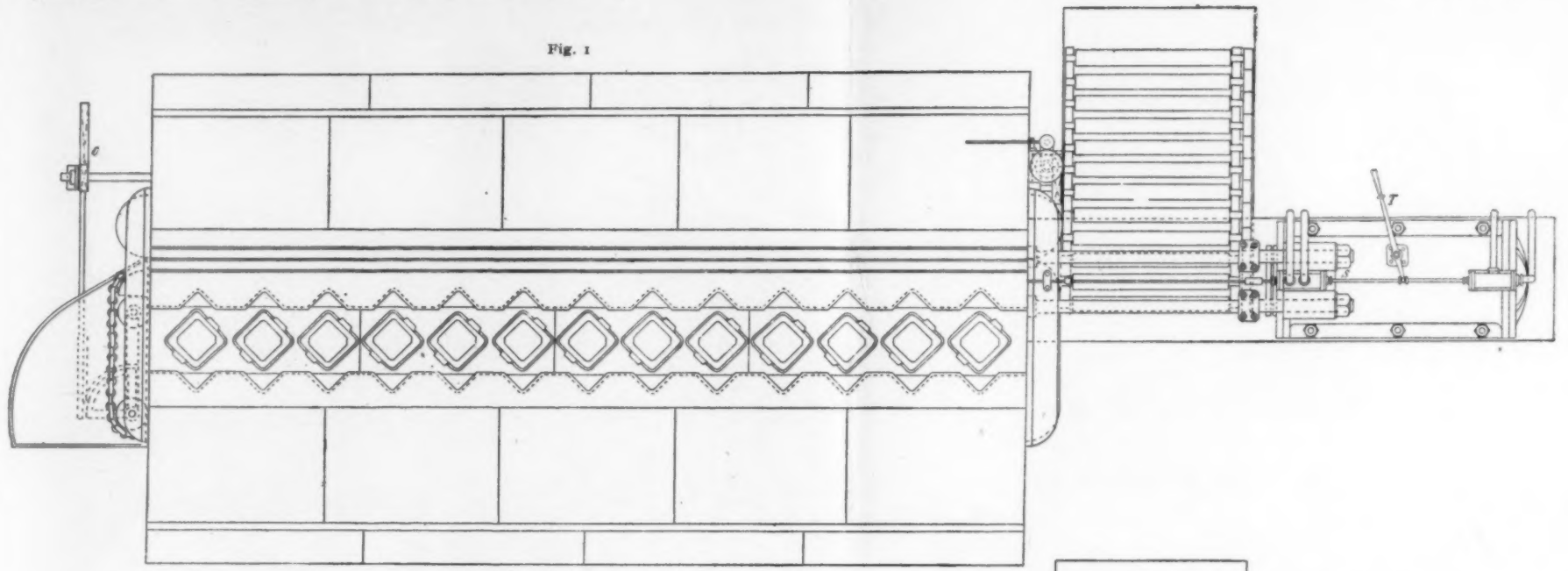


Fig. 2

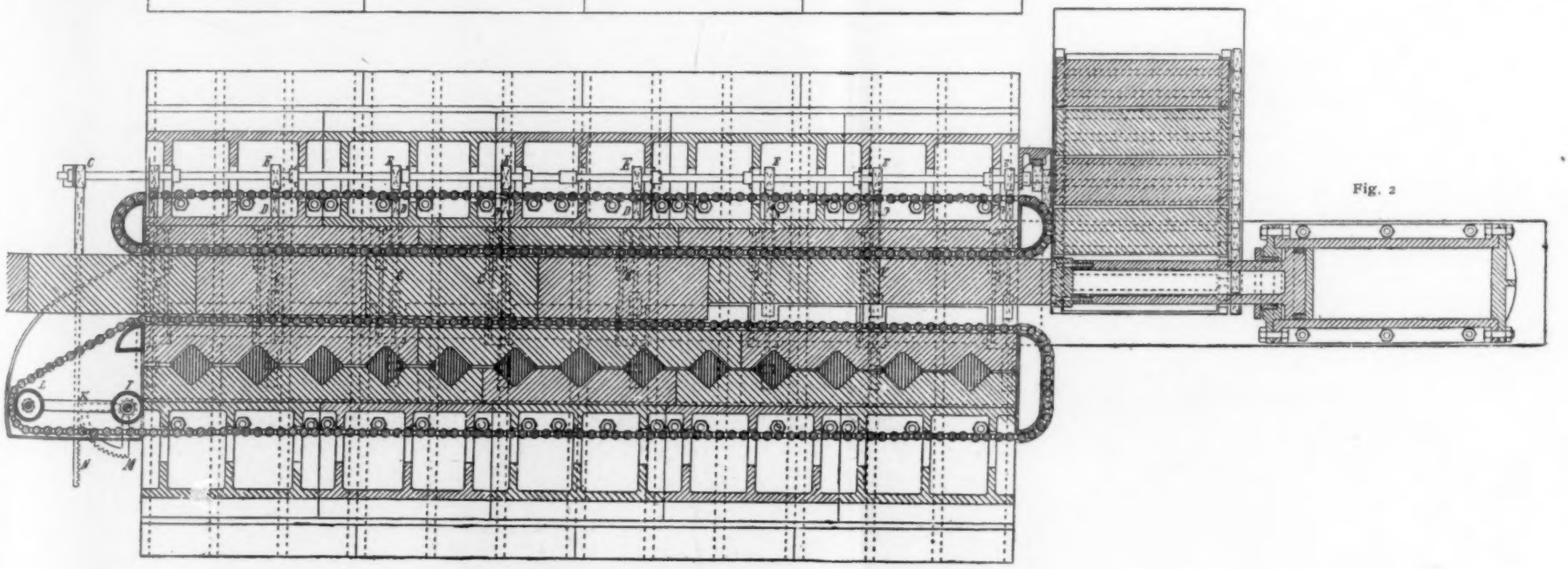


PLATE 5. Continuous press for steel ingots cast in pit.

there will have to be a great number of them, as one ingot cannot be treated at the time, because the following would then cool off.

(B) *Placing the stripped ingot* in a corner and working on it from two sides by hydraulic rams, after which it is allowed to fall through the bottom and be carried away. This works all right with one ingot, provided it really can be transported into the corner in its weak state. But the compression will have to be continued during the whole period of solidification and consequently the following ingots will get cold before the first one is finished. It would therefore be necessary to have a great number of hydraulic cylinders for compressing all ingots at the same time, which would be very expensive, both in construction and manipulation. Besides, it would be impossible to apply this system on the largest quantities cast on trucks.

(C) *Leaving the stripped ingots standing* where they are and act on the whole row simultaneously with a battery of hydraulic rams placed side by side, the whole of course being surrounded by a sufficiently strong frame. In this way the compression can of course be prolonged during the whole period of solidification and lifting the semi-liquid ingots is avoided.

It therefore seems that this could be used for ingots while standing on trucks. In carrying out this process we however meet with several great difficulties. The ingots will have to be moved a small distance sideways so as to release them and in case of casting on wheels to enable the locomotive to pull out the train without delay. This lateral movement should be made by the returning stroke of the hydraulic rams, but such machinery will not be easy to construct for a whole of ingots, especially considering that of the mold and trucks must be made free and clear from all constructions in one moment when the train shall be pulled out. If the ingots are pressed on the sides they will have to be caught in pressing between the projecting sides to take up the side swelling. The ingots will then get jammed in and an undue time and labor will be consumed in getting them out. This is of course avoided by pressing them diagonally, but placing the molds with the diagonals on the center line of the trucks, makes the whole train longer.

Such a whole battery of many hydraulic cylinders will be very expensive in construction. Each set of cylinders will have to be

regulated separately, as the first cast ingot having less heat than the last cast will have to be finished earlier. The finishing pressure on the steel will have to be about two tons per square inch. 18″ square ingot 60″ high, presenting a side area of 1080 square inches, requires 2160 tons final pressure assuming a water pressure of 2000 pounds per square inch in the total piston area of the hydraulic rams for each ingot will be 1210 square inches. There should of course be two hydraulic cylinders, one on top of the other, for each ingot, that is 605 square inches corresponding to 28″ in diameter. For a charge of twenty-five tons divided on ten ingots the number of hydraulic machines would therefore be twenty. If these ingots are standing on five cars to the total length of the train is about 32′, and the hydraulic cylinders with wall thickness and flanges placed side by side stretch out to about 36′. The center of each ram will have to point to the center line of the corresponding ingot. This may be somewhat difficult to adjust by only a locomotive pulling the train, and probably an additional adjusting apparatus would have to be made. The ingots are generally grouped two on each truck, close together, and therefore the corresponding hydraulic cylinder should also approach each other. The distance between the centers of two 18″ ingots placed on a truck is about 27″ while the centers of the 28″ hydraulic cylinders cannot be less than 35″, even if they are cast together. It may therefore be desirable to press each group of two ingots by only two hydraulic rams placed on top of each other, thus making the total number ten. The piston area of each will then be 1210 square inches and the diameter 3′ 11″. Such unusually large cylinders if made of cast-steel would have about $4\frac{3}{4}$″ wall thickness to resist the pressure of 2000 pounds per square inch. For a charge of fifty tons of course ten pairs of such large cylinders would be needed. The cylinders must not be laid too close to the ingots as otherwise the pistons may swell from the heat, the contact being extended over a long period. Therefore the width of the apparatus will make the apparatus occupy a large floor space. The pressure continued during the whole period of solidification will have to be modified according to the different stages. This is almost impossible to do by hand for a large number of hydraulic, especially on a small stroke of a few inches. The movement is then liable to be done by jerks with the consequence that the liquid steel is thrown out violently

and corresponding stratas and layers be formed in the ingot. It is thinkable that the valves could be moved by wormwheels, but as said before the speed has to vary at different periods and the pistons working at the first cast ingots should finish their work so much earlier than the last cast as the difference in time of casting. Such an automatic apparatus would therefore present a rather complicated mechanical problem.

From the above said, it thus seems as if there is no method for making solid ingots which is suitable for the largest quantities of medium size, especially for those cast on cars. At the same time, the desire is as great as ever before to lessen the waste and crop ends to obtain the proper and reliable structure of the steel with less rolling and forging than at present, and also to lessen the segregation. The question then forces itself on us. Is it possible to accomplish this in a practical and sufficiently economical way? Looking over the requirements again we find them standing as follows:

1. The casting should be made without changing the ordinary solid tapered molds but the ingots stripped earlier than usual, which can be done.

2. The stripped ingots should not be removed from their places on the bottom until the compression is finished.

3. In order that the pressure may be continued according to the solidification, all the ingots will have to be pressed simultaneously, but they must be finished at different periods, according to the difference in heat between the preceding and following ingots.

4. This should arrange itself automatically without any special attendance and the work of hauling, etc., should be reduced to a minimum.

5. The installation should be sufficiently simple and not occupy too large space in a steel works.

To all appearance there is only one way to accomplish this:

Leaving the early stripped ingots standing inside of a framework, pressing the whole row of them simultaneously by a wall moved forward by driving in wedge blocks. As the construction is patented, I hereby give some details.

Pressing the Stripped Ingots While Standing on Trucks. The drawings Nos. 1, 2, 3, represent the case of a forty-ton charge divided between eighteen ingots 18″ square, 60″ high, weighing about 2¼ tons each.

On the drawing No. 1, Fig. 1, shows the press (A) and the ingot train (B) during casting. The molds can remain the same as they are now, but the bottoms should be made so as to extend whole under each group of molds. As early as practicable after casting the ingots are stripped. For this purpose it is desirable that the taper of the molds as well as their inside condition is such that the stripping can be done by ordinary plunger. For this size of ingot the stripping should be done not later than fifteen minutes after casting when a crust is found sufficient to hold the liquid interior.

On the drawing No. 1, Fig. 2, represents the train (B) moved nearer towards the press (A) and with the stripped ingots. Three ingots are placed on each car although the number is generally two. On each group of ingots have been placed *frames of cast-iron* (D) filling up the space between the ingots and the outside plates provided with ridges are inserted by the lower end between the ingots and flanges on the bottom plate. These frames are simple to make, and as they do not need to be lifted to the full height of the ingots but can be shoved in sideways, the placing in position of these six groups of frames by travelling crane will only take a few minutes. No special care need to be taken to get them in exact position sideways, because the press will afterwards take care of that. These frames serve the following purposes:

1. To keep the ingots from falling when the stand stripped on the moving cars unsupported by the molds.

2. To take up the side pressure during the compression. This side pressure from the swelling would be equal to the front pressure if it were the question of treating an entirely liquid substance, but the solid outside steel makes it here only a part of the front pressure growing smaller in proportion to the solid steel increasing in thickness.

The frames are left on the ingots until the train has departed from the press and reached the soaking pit, where they are easily taken out at the same time with lifting the ingots. The width of the frames is so much less than the width of the ingots as the amount of pressure, which in this case would be about three inches. The stripped ingots standing on the train are immediately backed up by the locomotive so as to enter the press, as shown on drawing No. 1, Fig. 3. No special care need be exer-

cised to get the ingots in exact position in the press, as it is only needed that all of them are inside the apparatus.

The drawings Nos. 2 and 3 show the installation and operation of the machine.

On the cross section Fig. 3 (No. 2) the ingot (A) is shown as caught between the two walls. The movable piece (B) is pressed by the wedge block (C) being forced in between the stationary wall (D) and the movable one (B).

Roller bearings are placed between the wedge blocks and the walls, as otherwise an extravagant expenditure of force would be needed. These are made very simply of solid rolled steel with the ends set off and inserted into links, as shown on Fig. 4 (No. 2.) The link chains turn around half-round surfaces on each end of the press, as shown on the plan on drawing No. 2. The returning idle parts of these link chains and roller bearings move the one outside the fixed wall, the other inside a cavity in the movable walf, as shown at (E) and (F) (Nos. 2 and 3). The links holding the rollers slide between channel irons fixed to the walls. The lower of these contains steel balls on which the links can roll. It should be remembered that the movement will be so slow as about $\frac{3}{4}''$ per second, and that therefore these roller bearings do not have many of the inconveniences attendant to ordinary rapid roller bearings. The wear is of course comparatively small, also the inclination to tilt, which in roller bearings is more apparent in conical than in cylindrical rollers. To steady them against tilting, if such should appear, the chain can be made to contain plates at a few points having rollers inserted and made like hinges to bend around the ends. These link chains present the advantage over other roller bearings that they can be inspected during the open passage around the ends, and it is easy during the slow movement to exchange any broken or worn part.

The *wedge blocks* are in this case 6′ long, 3′ 9″ high. The ends stand at right angles to the side gliding against the fixed wall and the opposite side is tapered. As the time of compression is about twice the time of casting, the first cast ingot placed in the front end of the press should be only half pressed through when the lastly cast ingot at the other end begins to be pressed. With a compression of 3″ the tapering of the wedge blocks should therefore be $1\frac{1}{2}''$ on the blocks moving in the press at the same time, that is about $\frac{1}{8}''$ per 6′ length. Beginning with a thickness

of 12″ the last end of the blocks should therefore be 15″. It is easy to make the total slanting surface of the blocks slightly curved so that the pressure is automatically changed according to the different periods of solidification. The wedge blocks should preferably be made of steel and planed on all sides, but if this should be too expensive, some good cast-iron chilled on the two long sides can be used. As the blocks are driven out from the press they are taken care of by the travelling crane, returning them in groups to their position as indicated in No. 3, Fig. 2. This is the only actual handling during the operation. It is obvious that machinery could be constructed for returning the idle blocks, but there seems to be no need of this additional complication, as the travelling crane generally is at leisure during the compression. The blocks stand on rollers ready to be fed in before the hydraulic rams one by one by a simple mechanism. The rollers are connected by cog wheels and by a rack with slanting teeth, which is moved back and forth from two corresponding cog wheels (T) and (U) fixed on a vertical shaft. The upper of these cog wheels engages in a short rack fixed on the cross head of the hydraulic piston rods. It is thus apparent that the movement of the pistons feed in the blocks automatically into position for the next forward stroke. The last wedge block is driven forward by blocks with parallel sides leaving a clearance space of 3″. When all the wedge blocks are driven out the movable wall is thus released and can be moved backward.

The release is then effected automatically by draw-bars (G) hooked on the top of the movable wall. These bars are connected with levers (H) on which the weights (I) hang.

The Hydraulic Compressor is composed of two cylinders (K) and pistons (L), which in this case have a stroke of 7′. The piston rods are 10″ in diameter, which is somewhat more than is needed for the strength in order to reduce the consumption of water at the returning stroke. The front ends are screwed to a cross head (M) which is guided by sliding on the bolts (N) which connect the cylinders with the press. The valves are here made as revolving discs, but can of course just as well be piston valves if this should be preferable. As the returning stroke must be made quickly in order to save time, the corresponding outlets should be made larger than the inlets and a separate exhaust valve is therefore placed at the lowest point at the rear end of the cyl-

inders. The movements of the valves are automatical by connecting them with a sliding bar (P) provided with lugs which are pushed by the movement of the cross head.

The construction of this machine is not difficult to execute and it does not contain more movable parts than several appliances in a steel works (for charging, etc.). It is evident that the automatic movements reduce the attendance, and this consists in fact only by the work of one machinist in regulating the hydraulic pressure and looking at the proper movements of all parts. It is the only machine in which all the ingots are finished automatically in order according to their solidification.

Calculations are made in this case as follows. The information of the resistance of steel from about one-half ton per square inch semi-liquid until about thirty tons to eighty tons when cold (depending on the carbon) is rather meagre. It is desirable that in the present case the final pressure should be about two tons per square inch. This is provided that the front of the ingots are cast convex and pressed flat. The surface of the ingots in this case is $18'' \times 60'' = 1080$ square inches requiring 2160 tons. The total pressure on eighteen ingots will thus be 38,830 tons. The net power to move the wedge blocks lengthways will be obtained by multiplying with the taper and dividing with the length, that is $\frac{38{,}830 \times 3 \text{ in.}}{2 \times 52 \text{ ft.} \times 12 \text{ in.}} =$ about 93 tons. To this has to be added the pressure for overcoming the friction. If the wedge block were moving direct between two surfaces this would be $2 \times 0.10 \times 38{,}830$ tons $= 7{,}776$ tons, but the 4″ rollers reduce this to $\frac{1}{4}$ (2 x 0022 x 38,830) $= 428$ tons, that is 856 tons for both sides. The total power would then be $856 + 93 = 949$, to which 50 tons ought to be added for extra frictions and work, making the total 1000 tons. The hydraulic pistons are here 24″, total area 904 square inches, and maximum water pressure would then be $\frac{1000 \times 2240}{904}$ $= 2500$ pounds per square inch. The volume of water needed for one forward stroke is here 3.14 sq. ft. x 7 x 2 = about 44 cu. ft., and for the return stroke $3.14 - 0.54 = 2.6$ sq. ft. x 7 x 2 = about 36.5, which makes totally for a double stroke 80.5 cu. ft. This being repeated twenty times, the volume of water is 1610 cu. ft. By multiplying the volume of water with the pressure, the mechanical labor is gotten. As the maximum pressure of 2500 pounds per square inch is only needed towards the end of the operation the medium water pressure can be put at 1500

pounds per square inch. The total amount of labor will then be 1500 x 144 x 1610 = 347,760,000 pound feet, and assuming a period of compression of 45 minutes, the mechanical labor per second will be 128,800 pounds feet, which divided by 600 gives 214 horse power net for the hydraulic pump.

The cost of construction and installation is difficult to obtain even approximately, especially as the prices per pound vary according to the work made on different pieces. At request I have, however, made the following estimate for a machine treating twenty tons divided on ten ingots 17″ square 55″ high, standing on five cars, the train occupying a length of thirty-two feet.

THE FRAME WORK.			
10 stationary ridged plates of cast iron...373,700 lbs.			
1 stationary wall near the ingots.....212,460 lbs.			
1 movable wall .....232,420 lbs.			
	818,580 lbs. at 2c	$16,370	
28 bolts 5-½″x15′.....	33,240 lbs. at 3c	997	
56 nuts	13,380 lbs. at 6c	800	
56 cross pieces under the nuts.	13,475 lbs. at 2c	270	
8 channel irons.....	34,315 lbs. at 2½c	85	
20 bearings for the movable wall.....	9,030 lbs. at 6c	540	
			$19,835
THE PRESSING APPARATUS.			
15 wedge blocks 6′x3′9″x13″.....172,090 lbs. at 3c		$5,160	
375 rollers of cold rolled steel 4″x42″....	56,250 lbs. at 3.5c	1,970	
Lins for do.....	9,730 lbs. at 6c	584	
Channel steel	7,060 lbs. at 2.5c	175	
Other appliances.....		470	
			$ 8,359
FEEDING APPARATUS FOR RETURNING BLOCKS.			600
FRAMES AROUND THE STRIPPED INGOTS, 31,505 lbs. at 3c			945
HYDRAULIC PRESS.			
2 cylinders 24″ diam. 6′ stroke.....	35,955 lbs. at 6c	$2,156	
2 piston rods	5,490 lbs. at 6c	329	
2 pistons	2,820 lbs. at 6c	329	
Valves.....		200	
1 cross head.....	1,500 lbs. at 6c	90	
Connecting bolts.....		275	
Bottom plates.....		200	
			3,420
Total			$33,159

PRESSING THE STRIPPED INGOTS WHILE STANDING IN A CASTING PIT.

The same principle as previously described is applied to this case but the construction of the machine has to be different as illustrated in the drawings Nos. 4 and 5.

The case selected for illustration is a 10-ton charge divided on thirteen 12″ ingots. As the stripped ingots must not be removed the casting pit will have to be contained in the press and sufficient space given for lifting the molds, handling the ingots, changing the bottoms, and getting down into the pit for cleaning. The distance between the movable and the fixed wall will therefore have to be greater than in the previous case and the movement of the movable wall back and forth will have to be made by special machinery before the pressure with the wedges is applied.

The frame is composed of castings (A) sufficiently strong to take up the pressure and bolted to the bottom plate (B), which is ribbed so as to resist the breaking strain. This arrangement is made necessary because the top of the casting pit cannot be obstructed by transversal bolts tying the two sides together.

The apparatus for moving the wall laterally before compressing and after the operation is finished consists of bolts (C), which are to be seen on the section plan No. 5, Fig. 2, and on the transversal sections No. 4, Figs. 4 and 5. These bolts are connected with racks (D), moved by pinions (E), which are mounted on a shaft running the whole length of the machine. On the fore-end of this shaft a cog wheel is moved by a vertical rack which is pushed up and down by a hydraulic piston in the cylinder (F).

The side pressure of the ingots is taken up by placing them diagonally and arranging the grooves in the pressing walls accordingly. The pressure is therefore done obliquely on two sides and the ingots are released without extra work after the pressure. As stated above this construction could not be applied to ingots standing on the cars. The bottom for the molds stands on a layer of fire-bricks in which grooves are taken up so that the lower part of the projections in the movable wall can move forward sufficiently to shove the stripped ingots into the recesses before compression begins, all of which movements are illustrated by Figs. 4 and 5, drawing No. 4. After the compression the mov-

able wall is drawn backward half of the free space before the hooks (G) catch into the projections (H) on the under side of the bottom plates, after which these plates with the whole row of pressed ingots are simultaneously drawn backward and the ingots after pressing will thus stand in the middle of the casting pit ready for removal. On both sides of the bottom plates and the foundation of fire bricks there are two gutters into which dirt can be scraped and rinsed out from the end.

The wedges will, as in the preceding case, have to form a length together equal to the double length of the apparatus for the reason as stated above, that the first cast ingot should be about half compressed when the lastly cast is beginning to be worked on. These wedges will have to be so thick as to fill up the whole space, that is, considerably larger than in the preceding case. They are driven out by blocks with parallel sides which leave a clearance space, all of which is shown in the horizontal section Drawing No. 4, Fig. 2. These last named blocks will have to be lifted up and removed from the apparatus by travelling crane before the movable wall can be drawn back.

The roller bearings are moved by chains as in the preceding case and the returning empty chains move inside of the fixed walls as plainly indicated on the sections of the drawings. When the movable wall is shoved towards the fixed one this chain gets slack. For the purpose of keeping it in order the following apparatus is constructed at the rear end of the machine, as indicated on the Figs. 1 and 2, Drawing No. 5, and on the Fig. 1, Draw. 4. A shaft carries a cylinder (I) and two arms (K) which are bolted to another cylinder (L). When these arms swing out 90° the roller bearing chain is lengthened correspondingly and the slack taken up. This movement is effected by the cogsector (M), which is worked on by the rack (N) connected with the bar at the other end of which another rack is moved by the cog wheel (O) placed at the end of the shaft.

The transversal motion of the sections of wedge blocks for feeding them into the press at each stroke is made by placing them on rollers (P), see Figs. 2 and 3, Draw. 4. These rollers move in bearings contained in two transversal beams, as indicated. The front end of the tops of these rollers are connected by cog wheels. Only every other of these are keyed on the tops and

those between them are running loose. By thus giving away the movement of the half number of the rollers the simultaneous motion can be imparted by a less number of cog wheels. The rear end of one of the rollers nearest to the vertical cylinder (F) is provided with a cog wheel which is moved by another cog wheel counted on the main shaft close to the vertical rack. By a special clutch the cog wheel can be connected or disconnected with the roller. It will thus be seen that the vertical hydraulic apparatus is used for feeding the wedge block forward when it has finished moving the walls for pressure. It is obvious that another clutch will have to disconnect the vertical rack from the main shaft during the time when the apparatus is used to move the blocks side ways.

The cylinder for moving the blocks forward contains in this case only one ram, as the heighth is smaller than in the preceding case. The piston of this ram is of larger size than needed for the strength in order to save the volume of pressure water during the backward stroke. The cross-head is guided by the two bolts (Q), which also serve to tie the upper part of the cylinder to the transversal beam (R), which is bolted to the frame of the press. On the upper side of the cylinder are located two systems of balanced cylinder valves moved by a rod (S). At the end of the forward stroke the cross-head strikes against a lug fixed on this side and thus moves the valve and causes the returning stroke automatically. The openings in the valves are so arranged that the returning motion is more rapid than the forward. At the end of the back stroke the movement can be made either automatically by the cross-head striking against another lug, or by the hand lever (T), which in this case probably would be preferable.

Calculations: As above stated a 10-ton charge divided on thirteen 12″ ingots is here selected as illustration. The diagonal width of one ingot is 17″ and the length being 48″, the area presented for pressure of one ingot will be $17'' \times 48'' = 816$ sq. in. At the final pressure of 2 ton per sq. in. and on thirteen ingots will then be $816 \times 13 \times 2 = 21216$ tons. It is presumed that a pressure of $2\frac{1}{2}''$ is sufficient. The length of the press is 30′ 6″ and the double length therefor 61′. The new power required for moving the wedge blocks will therefore be $\frac{21216 \times 25}{61 \times 12} =$ about 72 tons. The friction in the roller bearings will according to the formula stated in the preceding part be equal to $\frac{2 \times 0.022 \times 21216}{4} =$

233 tons, and therefore on both sides of the wedge blocks $2 \times 233 = 466$ tons. The total end pressure will therefore have to be $466 + 72 = 538$ tons. Adding different friction we will make this even 600 tons. The diameter of the hydraulic cylinder is 30″ corresponding to an area of 706.86 sq. in. By dividing this into the total pressure in lbs., viz. 600×2240, the water pressure required per sq. in. will be about 1900 lbs. With this pressure given the product obtained by multiplication with the length and number of strokes will give the total expenditure in lbs. ft. and this divided by the time and with 600 lb. ft. per second will give the net amount of horse power required by the hydraulic pump.

In order to demonstrate the formation of pipe I have experimented with melting different materials and found that paraffine most closely resembles steel in its solidification. I have therefore made the model here exhibited in which a charge of paraffine ingots can be seen compressed as described above. It is also easy in this way to see the difference if compressing too early or too late which I can here show with samples.

Betz Building, Philadelphia, Pa., Dec., 1907.

MONEY STRINGENCY IN CANADA.

While there is no apparent slackening of trade in Canada, its activity is being reined in by the financial stringency. That is to say, the demand for merchandise of all kinds keeps up, but the expansion which other conditions would appear to warrant is not going on at its former rate, owing to lack of funds. In every part of the country confidence is in as good tone as ever, and many concerns would enlarge their works and add to their equipment if only the money were forthcoming for such expansions. The point should be emphasized that, whereas tightness of money is not uncommonly due to mistrust of trade conditions, in Canada's case it is attributable to abounding faith in the trade conditions. The great volume of trade has, so to speak, sapped up all the available money, and there is no margin for continuing the onward movement at the same rate. Every bank has now more good customers than it can keep supplied, and therefore has to curtail the accommodation it gives to each, advising many that for the present they must positively give up new capital projects and continue on their existing scale of operation. For a manufacturer to turn out as much product this year as his works produced last year more money is required, for the prices of material are higher, and in many cases so is the rate of wages.—*Iron Age.*

ELECTRICAL SECTION.

(Stated meeting held Thursday, December 5, 1907.)

Process and Apparatus for the Production of Carbon Bi-Sulphide in the Electric Furnace.

By Edward R. Taylor.

The application of electricity is fast revolutionizing many industries, and perhaps no other field is more inviting for this revolution than the chemical.

Many reactions require heat for their accomplishment, and also the materials of the reaction to be kept apart from combustion reactions and products. Retorts and crucibles have served for these separations, and are made of many different materials, oftentimes very expensive. Even this is not their worst defect. All are limited in size, and when it comes to a large production of any product so manufactured, it can only be had by multiplying these small retorts or crucibles.

Again, except in the case of platinum or other expensive materials, the life of these retorts or crucibles is very short, for they are subject both to the corrosion of the materials within them and the intense heat to which they must be subjected, to bring about the required reaction.

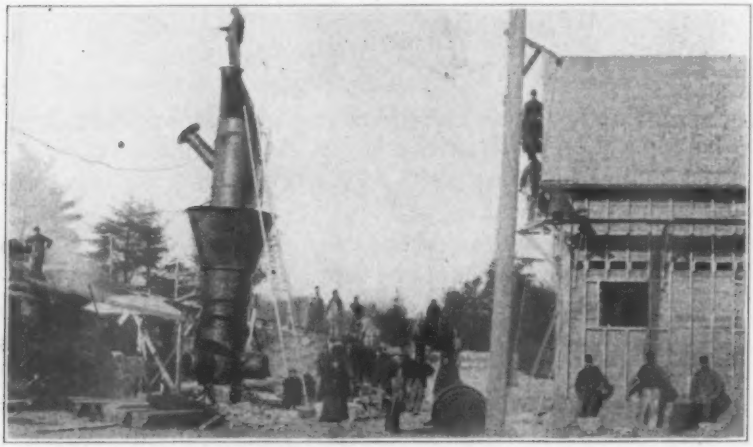
Oftentimes their cleaning is very troublesome and expensive. They are generally bad conductors of heat, and last and by no means least, they constitute a very wasteful application of heat.

From a manufacturer's point of view, their greatest defect is their limited size which leads to the multiplication of these retorts or crucibles for any larger production of goods. There is probably no one in all the past who has been obliged to use these who has not racked his brain for some way—I was going to say, out

of them. Well, let it stand—it probably conveys my meaning, if it is not strictly literal.

Being in the manufacture of bi-sulphide of carbon, which in retorts is one of the most disagreeable of all our manufactures, I, too, racked my brain, and am glad to say that I succeeded in racking it to good purpose. As I see it now, it seems to me peculiarly fortunate that this particular production should have been one of the first to get out of the retort. This feature will have our attention further on.

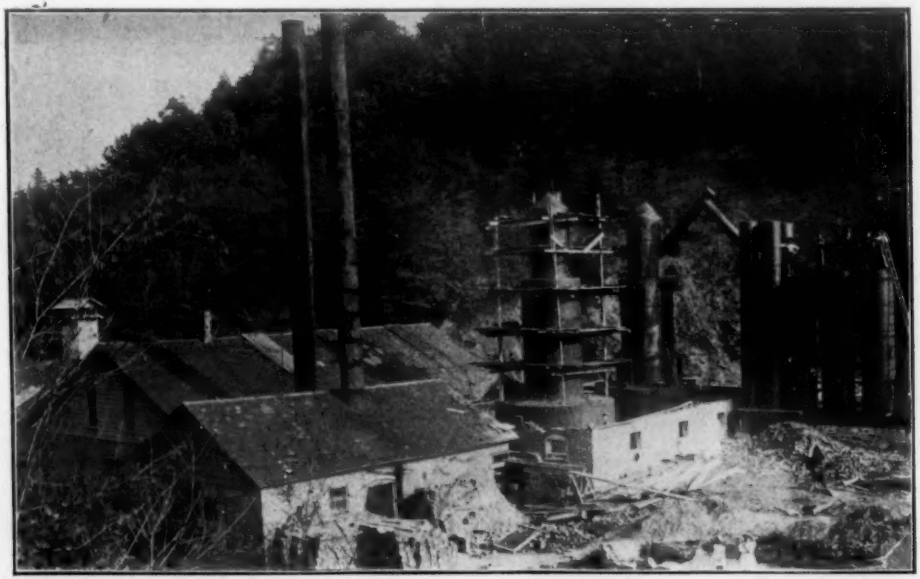
My first demonstration was made in Pittsburgh, in 1893,



First furnace 4 ft. diameter and 23 ft. high.

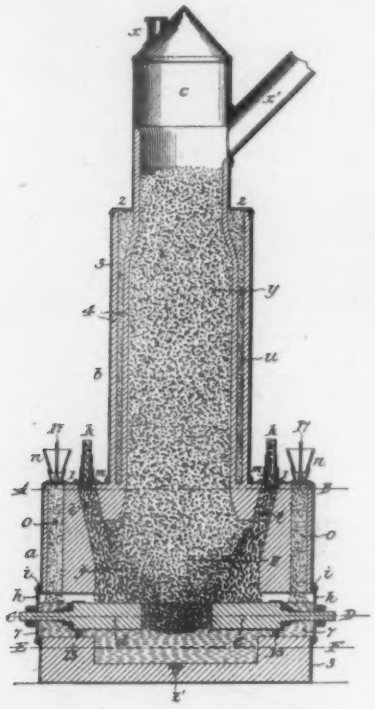
through the courtesy of our lamented Captain Alfred E. Hunt, of the Pittsburgh Reduction Company.

The first furnace for the industrial production of bi-sulphide of carbon was four feet in diameter and twenty-three feet high. It is illustrated here in the blue print and also by the lantern slide. Four feet in diameter was much smaller than my best judgment dictated, as I felt the heat would be too intense, and it did not afford sufficient room for the movement of the material. A vindication of this conviction came early. The sulphur was melted in the surrounding jacket, and while being hindered one time in feeding sulphur, the heat became intense and soon spoiled the shell of the furnace. Fortunately there was on the ground a



16 ft. x 41 ft. furnaces during construction.

still seven feet high and ten feet in diameter, and I at once determined to cut off the furnace, after supporting the upper part, and substitute this still for the lower part of the furnace. A large door and part of the side wall of the building had to be removed to get it into position. We were soon in shape again. That was a grand move and we had room in which to do something. While this enlargement was a great advance over the



Showing electrodes and chimneys for reinforcing with broken carbons.

previous construction, we being able to make about 5,000 pounds per day with 100 horse power, we could run it but four or five weeks till it had to be shut down, cleaned out and electrodes renewed. This usually required three weeks, including time for it to cool off. This was money expense without income. The demonstration of the larger furnace was so overwhelmingly successful that the next construction was made sixteen feet in di-

ameter and forty-one feet high. This is the size of the furnaces now in use, and they have more than confirmed the advantages anticipated for them. We can run these furnaces more than a year before renewing the electrodes or cleaning out.

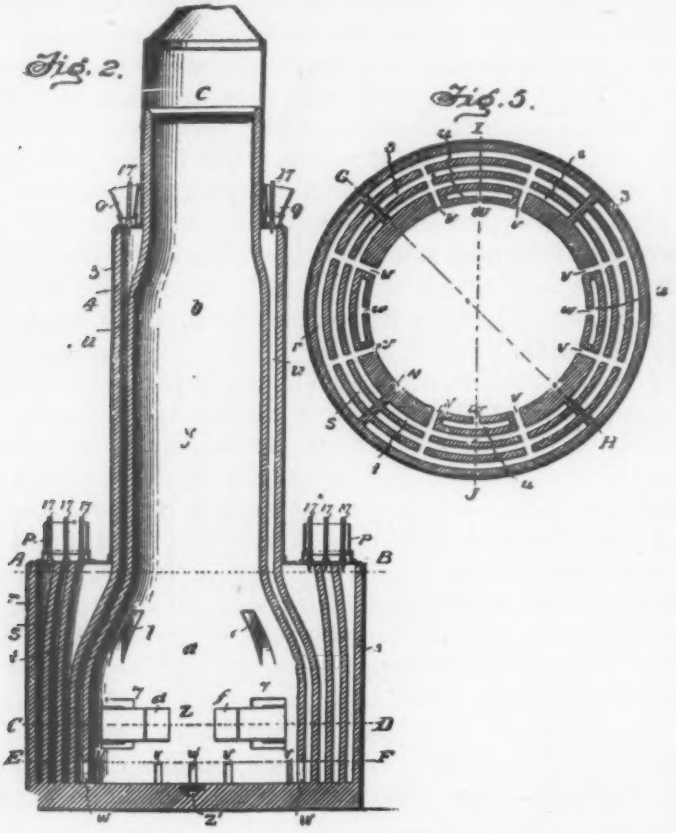
Each composite electrode in this furnace is composed of twenty-five carbons each 4″ x 4″ x 48″ making a complete electrode twenty inches square and forty-eight inches long. We use two phase alternating current and four of these electrodes. In the center of the furnace they are about twelve inches apart. Chimneys above each of these electrodes are used to convey broken carbons down upon them and over their ends. Their action breaks up and diffuses the current, which instead of being of one or two arcs, is broken up into a multitude of little ones, but these probably disappear as the furnace heats up. This moderates the intensity of the heat, stops entirely the hissing of the current, so common in arc furnaces, and protects from excessive wear the main and more expensive electrodes, taking, so to speak, the brunt of the battle.

They also, if possible, serve a still more important purpose in regulating the current and saving the necessity of moving the electrodes through the walls of the furnace, which would be a very troublesome thing to do in a furnace filled with melted and vaporizing sulphur. This was a problem that presented very serious features in the early thought of a furnace for this purpose. The broken carbons also relieve the intense violence of the heat at the terminals. It will be appreciated that for low temperature work, like the manufacture of bi-sulphide of carbon, this is very essential. They also facilitate the starting and stopping of the furnace. Indeed the broken carbons are so valuable in this respect that we find we can stop and start at will, even when the furnace has become completely cold, and I cannot emphasize too highly the value of these broken carbons in a furnace of this construction.

By reason of these considerations, no furnace is more capable of abuse without harm than this. There is no noise, no violence, no sudden fluctuations in the passage of the current, and it never refuses to go.

Aluminum bars 6″ wide and $\frac{5}{8}$″ thick (shown in the lantern slide), connect the insulated electrodes with the two Stanley in-

ductive type dynamos, which are of three hundred and thirty kilowatts capacity each, and usually run by water power, but we have an engine to help out in times of low water. The voltage varies between forty and sixty, according to conditions in the furnace, but there are no sudden fluctuations in voltage and the average is about fifty volts.



Showing electrodes and channels in the periphony for sulphur.

To charge the furnace sulphur is filled in up to the top of the electrodes and broken carbons are added, including the filling of the different chimneys over the several electrodes and the shaft of the furnace is filled with charcoal, and the periphery spaces of the furnace filled up with sulphur.

With the larger construction it is easy to feed the cold and crushed sulphur around the periphery of the furnace, allowing it to find its way in the melted state into the interior heat zone.

Being progressively raised in temperature as it approaches the zone of reaction, the level of the melted sulphur is regulated by the amount of current supplied to the furnace and the amount of cold sulphur fed into the periphery.

On combination of the sulphur vapor with the charcoal, the formed bi-sulphide of carbon rises through the charcoal above it, heating it as it progresses downward towards the reaction zone.

Thus in this furnace, the heat seeking to escape by radiation, is continuously borne back to the reaction zone by the incoming material.

So complete is this return, that when making bi-sulphide of carbon at the rate of fourteen thousand pounds per twenty-four hours with the room at 16°C. the outside shell of the furnace shows temperatures at different points ranging from twenty-three to sixty-four degrees as a maximum. With yet more power in the furnace, the production would be greater and these readings still lower.

This brings us back to a point referred to before, with reference to this particular production for this demonstration of the conservation of heat in the electric furnace.

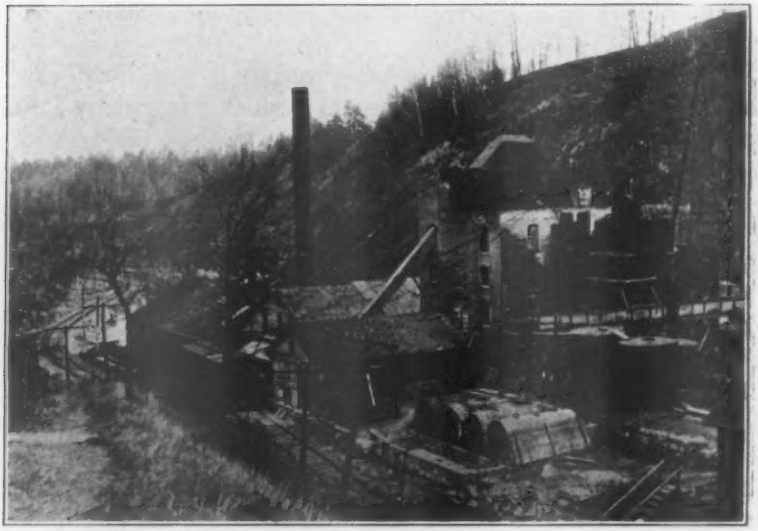
The low melting point of sulphur very much facilitates the development of this idea, and to my mind it is difficult to overestimate the value of this return of heat to the zone of reaction.

My ideal for an electric furnace is one where the outer shell of the furnace is merely a jacket as cold as the surrounding atmosphere and mainly serving to keep gases from escaping, and to direct the flow of the interior materials, the real walls of the furnace being one or more of the reacting materials completely surrounding the reaction zone, and continuously bearing back to the inside heat as constantly endeavoring to escape.

Graphically it may be represented by, say an egg-shaped interior, surrounded with reacting material constantly approaching and returning heat that has escaped from the hot zone, but cannot make its way out of the furnace itself, thus using the heat produced for the definite reaction in hand; this incoming material being of such thickness as to completely absorb all radiant heat.

It is now well demonstrated that this is easily brought about in case of material not too difficultly fusible, and one need not hesitate to work this principle on materials having a melting point very much higher than that of sulphur, which as we have seen behaves most admirably, for in this with sufficient power we could carry almost to perfection the ideal conditions above indicated.

No form of combustion can really compass these conditions, but this is made possible by this form of electric furnace. A correct balance of power to the size of furnace and materials used, is the key to this ideal result. It is obvious that this principle is of



Completed works, showing railroad facilities, stills for refining storage tanks, etc.

wide application and without doubt will be in the future largely applied.

In most electric furnaces the gases have been of secondary or of no consideration. But not so with the manufacture of bi-sulphide of carbon. It is gaseous in the furnace as formed and it is the thing we are after. We may therefore follow it out of the furnace through the pipe at the top and on to the condenser, shown in the lantern slide of the works in construction, after which it is refined for market by distillation. The stills for this

purpose are shown in the foreground of lantern slide of the works after completion.

It is obvious that any gaseous product from such a furnace can also be saved and utilized even should it be a by-product and not a main product, as in this case; as for example carbonic oxide, which could well be used in gas engines. For such use it would be much more valuable than producer or blast-furnace gas, as it is not diluted with nitrogen.

The bi-sulphide of carbon being an endothermic compound absorbs heat in its formation, and being in the vapor state at its formation also has its latent heat of vaporization with it, as also the high temperature of its formation. These actions are constantly taking heat away from the heat zone, and as noted, distributing it to the charcoal coming down and to the sulphur coming in from the bottom and the sides. By these means a comparatively uniform temperature in the reaction zone similar to the uniform temperature of a liquid when it has reached its boiling point is maintained. Thus the work balances itself. There are no sudden fluctuations of current in the furnace except the fluctuations of power outside of it.

For other reactions and other products a different temperature would be the normal one just the same as different liquids maintain their boiling points. This uniformity of temperature, very low or very high, may be continuously maintained for months at a time.

Nothing cold ever reaches the heat zone of this furnace. Sulphur or charcoal completely envelopes the heat zone. With the continued progress of the charcoal and the sulphur towards the heat zone there is the continual increment of heat, so that when they do reach the interior of the furnace both are at a bright red heat, the charcoal in a glow—and the sulphur in a state of vapor. The combination is immediate and the compound hurries upward, heating the charcoal in its path, being pushed on irresistibly by the material behind it.

We can modify the conductivity of the furnace by the feeding of broken carbons and by the height at which we carry the melted sulphur. Indeed we can completely cut off the flow of current through the furnace by allowing the melted sulphur to raise sufficiently high above the terminals. So the maintenance of a suita-

ble level of melted sulphur is an important factor in the operation.

So easy is it to maintain these necessary conditions that my man in charge takes great delight in running it. Often he says to me, "I have no words to describe how nice and easy this furnace runs. It is rest to run it. It is like driving a gentle horse. It is a great satisfaction to run it. No trouble here. It is just pleasure. This furnace is just grand." He even exhibits affection for it when he says "this dear furnace." Thus I am greeted with expressions of pleasure day after day. Think of the maker of bi-sulphide of carbon evincing such satisfaction with his work as this. I venture the assertion that no other process of manufacture of bi-sulphide of carbon calls from the man who runs it any such expressions of pleasure.

In Sicily I saw a plant where they used forty-eight retorts for making 10,000 pounds of bi-sulphide of carbon in twenty-four hours, and required thirty-five men to run them. When you consider that every few days these retorts had to be opened from the top and the ashes spooned out, sulphurous acid coming up into the faces of the men, you can imagine how disagreeable it is to attend to such retorts, every individual one of which must have more attention than an electric furnace making more goods than the whole of them. We appreciate things by contrast.

This blue print illustrates the retorts formerly used by me in this manufacture. The opening at the bottom shows where we removed the ashes from the bottom of them every ten days or two weeks. This was done while they were hot, lost us about twelve hours in time and was very disagreeable, but nothing to compare with spooning them out as just referred to in the Sicily works.

With the electric furnace the cleaning out is done with a cold furnace about once a year with no trouble or inconvenience.

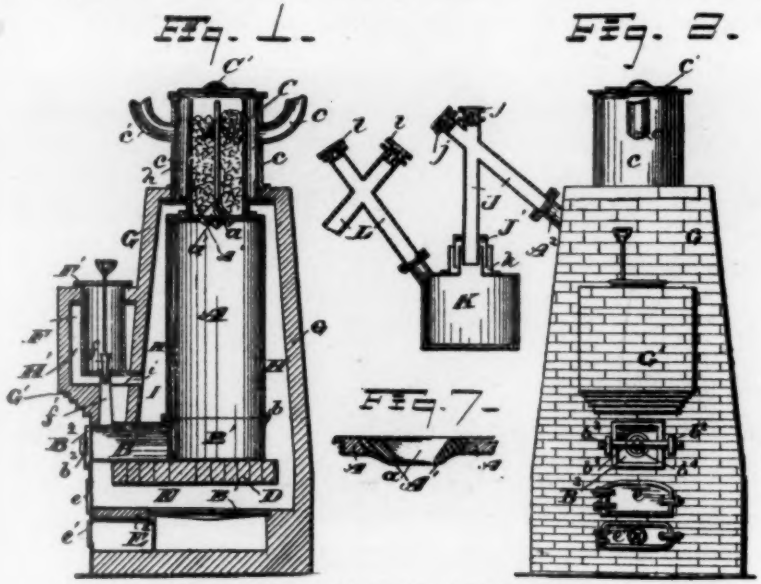
Just at this writing a telephone from the works saying, "Oh, it is fine, Mr. Taylor!" "You really do not take the comfort with these furnaces that I do."

This reminds me to say that we transformed an old paper mill into this chemical works—but the name "mill" will not leave it, so it comes to pass that I have the unique distinction of having a "chemical mill," whatever that may be.

When the furnace is in full operation, the charcoal is supplied through an opening at the top of the furnace to a hopper above a

bell similar to those used in blast furnaces. As often as there is room in the shaft below the bell the charger (holding about thirty-two bushels), is dumped and the charger refilled. In this place it becomes more or less heated, so it does not enter the furnace absolutely cold. A very strong endeavor was made to substitute coke for charcoal three years ago, but it was a failure and abandoned.

In like manner the sulphur is fed into the periphery from the hoppers above them, as often as is necessary to maintain the best working conditions, and it is very desirable that these conditions



Retorts formerly used for making bi-sulphide of carbon.

should be such as to keep these spaces full.

If the power is equal to the capacity of the furnace for producing goods, sulphur should be put in whenever there is room for it under all conditions.

As we are now working we can produce 14,000 pounds per twenty-four hours in one of these furnaces, but in so doing we are not able to keep the periphery of the furnace completely filled with sulphur to the top, which would be the ideal condition, had we sufficient power. This size of furnace is quite capable of pro-

ducing 25,000 pounds per twenty-four hours. It would be very interesting to note the temperature of the shell of the furnace with such a production. We always find the larger the production the more economical and the cooler the shell.

If on a production of 14,000 pounds the highest temperature of the shell is 64°C., may we not expect that on a production of 25,000 pounds in the same furnace we may closely approach the ideal condition of having the outer shell at a temperature but little, if any, exceeding the temperature of the surrounding air? Is it not a condition devoutly to be wished and is this not in a direction in which we may ultimately expect success?

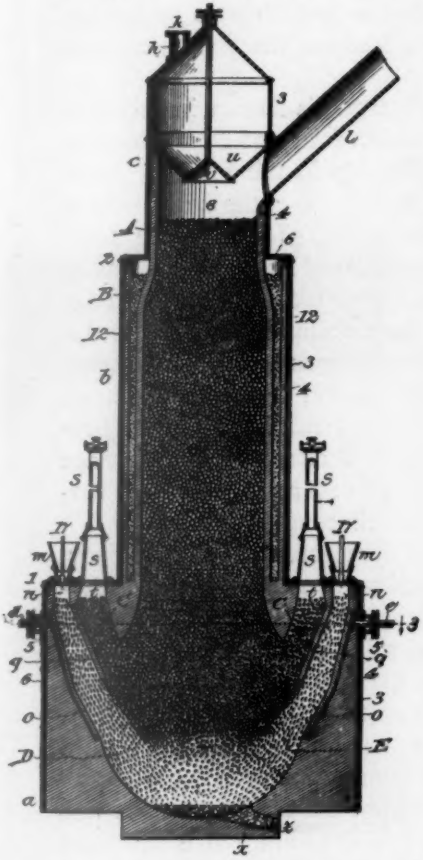
Showing electrode with packing gland-aluminum attachment, and insulated plate attached to furnace.

It may be interesting to trace the different intermediate connections between the carbon electrodes and the aluminum bars outside of the furnace.

We have in this blue print shown a socket of iron into which the carbons are inserted,—another cylindrical casting attached to this socket passing out of the furnace through a plate insulated from the shell of the furnace and through a packing gland similar to that of the piston of an engine. This is made large and is packed with mica and asbestos paper. This is done so carefully and is so complete that the most delicate magneto will give no

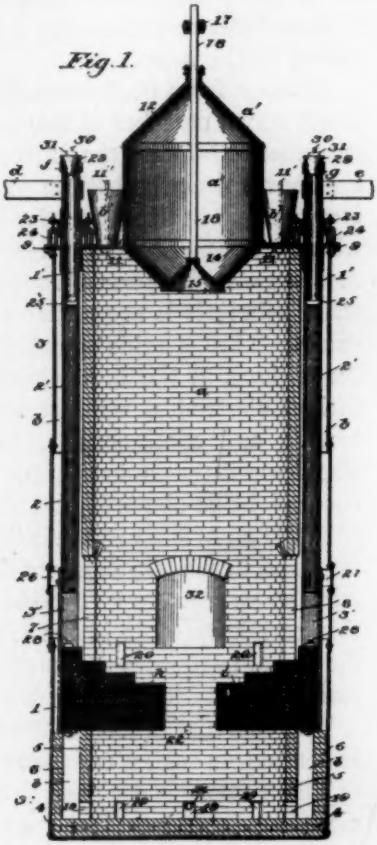
ring when connected with the shell of the furnace and one of the iron terminals.

This other blue print shows another form of intermediary where a metal chimney or tube is lined with carbons through which broken carbons are supplied, and which descend and are



Showing self renewing electrodes of broken carbons and charging bell.

Fig. 1.



Smaller electric furnace showing electrodes and connections.

replaced from above as they wear away. They take current from the carbon lining of the conductor and carry it to the center and towards the bottom of the furnace.

They may be further reinforced by other broken carbons, being fed in through S, at a point farther into the furnace.

It is designed to so feed them that the weakest part of the circuit will always be near the bottom of the furnace. The conduits are passed through the shell of the furnace higher up on the shell but in a similar way to the other form of electrode. This arrangement makes a continuous self-renewing electrode, the weakest point in the circuit being where the two streams of broken carbons meet near the bottom of the furnace, the broken carbons taking all the wear.

Another form of intermediary electrode is shown in this blue print, which partakes of features of both forms of electrodes just described. In this, the carbon electrodes in the form of steps, are shown near the bottom of the furnace, and the intermediary is carried up in the form of a box to the top of the furnace, from whence it is connected with a cylindrical pipe which passes through a stuffing box through the top of the furnace to the exterior where it is connected with the aluminum bars to the dynamo. Through this cylinder broken carbons are fed down upon the carbons at the foot where they fall out and over the main carbon electrodes, reinforcing them and making them self-renewing and continuous. This form of electrode and furnace was devised that a comparatively small and really workable furnace might be obtained that would be thoroughly efficient.

The shell of the furnace is lined with asbestos, as are the others, inside of which is a lining of brick of smaller diameter, and leaving a space between its outside and the shell of the furnace. Into this periphery space is fed crushed sulphur, which is melted by the radial heat from the interior of the furnace, settles down and makes its way into and at the bottom through similar openings.

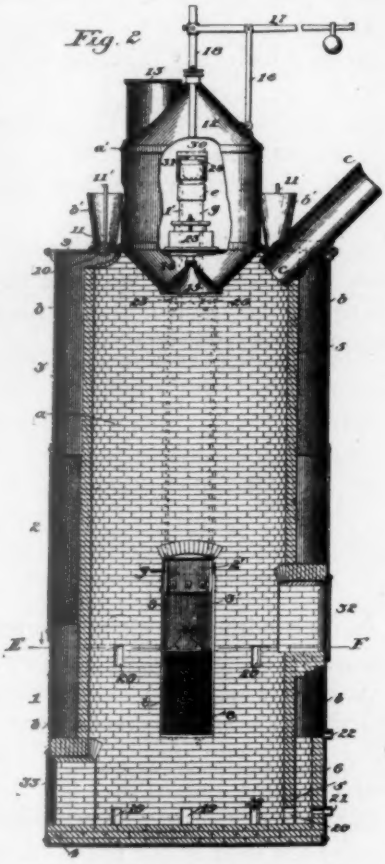
The charcoal is fed in through a hopper and bell as described in connection with other forms of construction.

This furnace is designed to be eight or ten feet in diameter and eighteen or twenty feet high, and will produce five thousand pounds per twenty-four hours with economy and satisfaction, while it could be pushed to a production of 10,000 pounds per twenty-four hours without trouble, with good advantage.

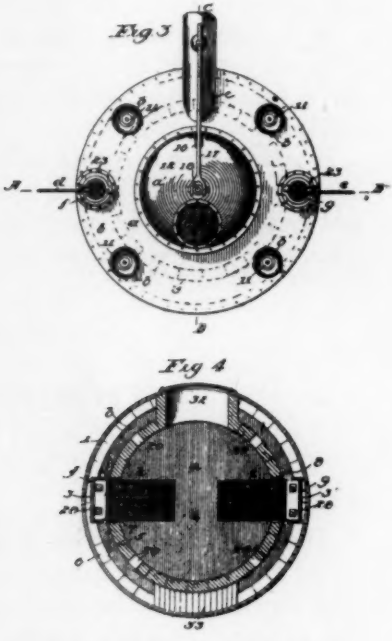
Two electrodes only are provided in this furnace, as a larger number would take up room more valuable for the materials of the reactions.

The broken carbons of course perform the same office as in the other construction.

The sockets which hold the main carbons are separate castings from that intermediary that connects with the outside of the fur-



Showing charging bell and sulphur space around the periphony.



Top view showing electrodes and connection periphony sulphur space.

nace, so if spoiled they can be detached and others supplied without the sacrifice of a large casting. Our experience is that these sockets can be used several times before they become so much injured as to require renewal.

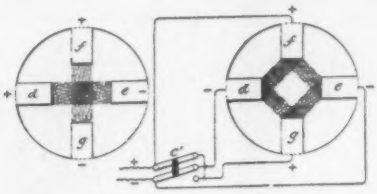
While this form was devised more especially for a compara-

tively small construction, there are principles in it that are very desirable in a large construction, and that will doubtless be so used.

With most electric furnaces the carbons figure up to a very heavy expense, but not so with these furnaces. The broken carbons are cheaper than the main carbons and are by this arrangement forced to the front, by means of which they take the wear and save the more expensive material.

To equip one of the large four-electrode furnaces with carbons costs one hundred and seventy-five dollars each time, but they last for a year or more without renewal, and make more than two million pounds of goods.

It will be seen that this combination of main and movable carbons in the interior of the furnace itself does away with the necessity of moving an electrode through the shell of the furnace from time to time and the insulation becomes permanent.



The four-electrode electrical furnace with two phase current to my mind presents many advantages. We usually pass the current through and through direct from one electrode to the other, but at any time when desired it can be changed to the adjacent electrode and then melt down or burn out any corners or pillars that may form and not be disposed to come down, thus any obstruction to the regular descent of the material may be removed. They also more completely centralize the heat in the hot zone of the furnace.

The electrodes are directly connected to the dynamo circuit without the intervention of transformers and the current regulated by the field and exciter reheostates with entire ease and satisfaction.

I doubt if the interior of the bi-sulphide of carbon furnace attains a temperature to exceed 1,000°, or at most 1,500° Fahren-

heit, and I would be prepared to see measured any temperature between these points as the practically constant temperature of the interior.

May I make my meaning clear without pretending to be literal, by saying the boiling point of the reaction.

For electric furnace work this is a comparatively low temperature. With other materials for a given reaction either a lower or a higher temperature may be the constant temperature.

There is a question as to the possibility of running a furnace of this type that will constantly maintain a very high temperature in the interior if the reacting materials will not be driven out or cannot be removed in a state of fusion, until such high temperature is attained; and we have proof of this in the first furnace four feet in diameter before referred to when the outer steel shell was so near the melting point that one of my men before I knew what he intended to do took a steel punch about sixteen inches long and pushed it through the shell as easy as though it were butter. Instantly I said, "Leave that there." What a nice time we would have had if he had pulled it out.*

There is no question about the ready application of these principles to other manufactures, especially when one of the constituent materials employed has a low melting point and good fluidity, like sulphur; and we may expect in the near future such developments.

For solid materials of difficult fusibility many difficulties present themselves in a furnace of this sort, but I am not without hope that such materials will ultimately be successfully worked; but it will have to be on a very large scale if at all, for solid bodies must have room in which to move to fulfill the conditions required,—quite likely mechanical action may be required to supplement the force of gravity.

As illustrating such a possibility, please notice the suggestion of such an endeavor illustrated by the blue print.

Between the interior hot reaction zone and the shell of the furnace which by the absorption of heat as it progresses shall keep the outer shell of the furnace at practically the temperature of the

*This high temperature was caused by our failure to feed in sulphur, thus giving the heat nothing to do but to accumulate in the interior till it had become so intense as to heat the shell as indicated.

surrounding air; with sufficient power in these present furnaces I believe this ideal condition could be reached. With this attained it is clear that the same ideal conditions can be reached with materials having much higher melting point than sulphur, and the use of this form of furnace not only greatly extended to other manufactures, but the practical size of furnace very greatly increased.

In this connection it is very interesting to note the progressive enlargement of the blast furnace, and to remark that nine blast furnaces erected during the first six months of the present year have a combined capacity equal to the entire production of pig iron in the United States in the year 1886, and which in that year required four hundred furnaces to produce. Yet of these nine furnaces built this year two of them were of such a size that seven such furnaces would be capable of producing more than the entire production of 1886, with its four hundred furnaces, and the probable maximum of large blast furnaces in all probability has not yet been attained.

Probably the blast furnace is the most economical furnace constructed, but the heating of useless nitrogen and the loss of heat from its sides is of necessity very great. It offers no such opportunity to cut off radiant heat as does the electric furnace, and while the advantages of increasing the size of blast furnaces has been very pronounced, the advantages of enlargement in electric furnaces are many times greater. Yet it must be admitted that most electric furnaces so far constructed have been very uneconomical, and especially wasteful of radiant heat,—yet in spite of these limitations the electric furnace is continually working into new fields, and will without doubt ultimately reach a perfection quite beyond the most efficient blast furnace.

Heretofore the gases from the electric furnace has been generally neglected.

It is very easy to see that an electric furnace constructed on the principles I have described is capable of utilizing all of the gases produced, and as no nitrogen is introduced the gases will be much richer and more valuable either for use in the gas engine or as a source of heat.

In the discussion on my first paper before the American Electrochemical Society, President Richards was kind enough to say:

"I think it is well to know that this furnace of Mr. Taylor's "has practically revolutionized the manufacture of carbon bi-sul- "phide in this country, and the size of the furnace is a revelation "of what may be expected in the size of electric furnaces in the "future."

May I also quote from my second paper before the same society at the first Niagara Falls meeting, *i. e.*: "In this connection "I will say that with this construction of the furnace and an ade- "quate source of electricity at my command, it would take less "nerve on my part with my present experience, to construct an "electric furnace that would dwarf the largest blast-furnaces "in existence to-day, than it took to build the furnaces now in use, "which are sixteen feet in diameter and forty-one feet high."

May I close this paper by quoting from a paper that I had the honor to read before the International Congress of Applied Chemistry at Berlin, in 1903, as follows:

"Having made provision for the movement and renewal of the "electrodes in the interior of the furnace itself, the introduction of "the conductor through the side or shell of the furnace (from "which it is insulated) is not only comparatively simple, but is of "a permanent character, and is shown at E in Fig 6. In this "construction, provision is also made at S for either the reinforce- "ment of these movable fragmentary electrodes, or for retarding "their conductivity by the introduction of non-conductive mate- "rial, or for the introduction of other material to be acted upon "in the furnace. A tap hole is also provided for the removal of "fused material.

"With these arrangements all the materials very gradually ap- "proach the heat zone of the furnace, and having entered into "combination under the best possible circumstances, the fused "product or residue makes its passage downwards, and the gase- "ous upwards, giving out heat as they go to the descending ma- "terial, and finally making their escape to the condenser through "the pipe shown at the top of the furnace.

"We have in this furnace the possibility of uniformly obtaining "the most suitable temperature (very high, very low, or any- "where between) for any given furnace reaction and maintaining "the same without fluctuation for days, weeks, or even months to-

"gether, a feature that will be greatly appreciated by working "chemists.

"All materials after having been once placed in the furnace "feed uniformly by gravity and fusion, giving such unity to the "whole as to give the best possible results from an economical point "of view, and creating in the mind of the worker a feeling of "great satisfaction, from the fact that troubles do not come to "disturb him and he can readily see a good reason for every- "thing he does. This encourages and stimulates his best endeav- "or and he becomes an enthusiast rather than a drudge, and his "labor a delight and pleasure.

"In most electric furnaces, more heat is wasted than is used. "In the one herein described, the loss is reduced to a minimum. "The whole operation takes place in a closed case protected from "any excess of heat, and lasts for many years without any import- "ant deterioration. The lining inside, after runs of many "months, requires only trivial repairs that are easily made. "When, therefore, to all of these considerations and others not "enumerated, it can be added that there is practically no limit to "the practicable size for such a furnace, except a market for the "goods and an adequate supply of crude materials and electricity, "its great advantages are obvious. We no longer need make bi- "sulphide of carbon in thimbles of furnaces; but any manufacture "it with ease in large quantities with an economy that ought to "largely extend its uses.

"As an illustration of the great advantage of a large furnace, "an earlier construction, ten feet in diameter and twenty-three "feet high, could be run continuously but a month or five weeks "at most, whereas, these sixteen by forty-one furnaces can be run "for many months in succession, and a furnace that would dwarf "the largest blast furnace in existence would probably offer cor- "responding advantages, both in economy and ease of manipu- "lation.

"We have made in this furnace fifteen thousand pounds in a "single twenty-four hours, and with more electricity in the same "furnace twenty-five thousand pounds can readily be made in that "time.

"It may also be said that the larger the furnace the easier it "can be worked, and it would seem that an operation that can be

"performed in a crucible, might be worked in this construction on "a scale almost bewildering to contemplate."

Coming now to our present gathering at the Franklin Institute, I may say, the market for bi-sulphide of carbon is a limited one and we cannot sell all we can make, and no larger furnace than those now in use would be justified under present conditions. But were the market for bi-sulphide of carbon as large and regular as the market for pig iron I would say the size of the future furnace need only be limited by the market for the goods and the amount of electricity available to put into it.

Book Notices.

NEW PUBLICATIONS.

The Universal System of Machine Moulding. Ph. Bonvillain & E. Ronceray. Catalogue. 96 pages, illustrations, 8-vo. Paris, n. d.

Pratt & Whitney Company. Small Tools, Standards and Gauges. Catalogue No. 4. 215 pages, illustrations, 12-mo. Hartford, Conn., Pratt & Whitney Co., 1907.

Pennsylvania State College Agricultural Experiment Station. Bulletin No. 71, revised edition. Relative value of feeding stuffs. Experiments with the respiration calorimeter in cöoperation with the Bureau of Animal Industry of the United States Department of Agriculture. 16 pages, 8-vo. State College, Penn'a, May, 1907.

Program and Papers. Brass Association Convention held with American Foundrymen's Association, May 20 to 24, 1907, Philadelphia. 26 pages, illustrations, 8-vo. New York, The Metal Industry, n. d.

Pennsylvania State Department of Agriculture. The Monthly Bulletin of the Division of Zoology, vol. 4, Nos. 11 and 12, March 1 and April 1, 1907. Plates, 8-vo. Harrisburg, Economic Entomologist of the Department, 1907.

U. S. Commissioner of Education. Report for the year ending June 30, 1905, two volumes, 1400 pages, 8-vo. Washington, Government Printing Office, 1907.

Forged and Rolled Steel Pipe Flanges special forgings, and full-size cross sections of flanges used in the different standards manufactured by the American Spiral Pipe Works. 93 pages, illustrations, 4-to. Chicago, 1907.

In opposition to the resolution reported from the Committee on Privileges and Elections. "That Reed Smoot is not entitled to a seat as a Sena-

tor of the United States from the State of Utah." Speech of Hon. Philander C. Knox, of Pennsylvania, in the Senate of the United States, Thursday, February 14, 1907. 19 pages, 8-vo. Washington, 1907.

U. S. Department of Agriculture. Farmers' Bulletin No. 277. The Use of Alcohol and Gasoline in Farm Engines, by Charles Edward Lucke and S. M. Woodward. 40 pages, illustrations. Washington, Government Printing Office, 1907.

University of Illinois Bulletin, vol. 4, No. 3, October 1, 1906. Chemical and biological survey of the waters of Illinois. Report for the year ending August 31, 1906, by Edward Bartow. Water Survey Series, No. 3. 30 pages, illustrations, plates, 8-vo. Urbana, University, n. d.

Investigation of the Thermal Conductivity of Concrete and the Effect of Heat upon Its Strength and Elastic Properties, by Ira H. Woolson.

Authorized reprint from the copyrighted proceedings of the American Society for Testing Materials, vol. 6, 1906. 25 pages, illustrations, 8-vo. Philadelphia, 1906.

Water Powers of Peru, their Development and Possible Applications. Utilization of the colossal hydraulic power of Lake Titicaca.

Abstract from the "Engineering Magazine." 8 pages, 8-vo.

Sections.

MECHANICAL AND ENGINEERING SECTION.—Stated meeting held Thursday evening, December 19, at 8 P.M. Mr. Charles Day in the chair. Present, forty-eight members and visitors.

The chairman introduced Mr. Axel Welin, A. I. N. A., London, England, who described and illustrated with the aid of lantern pictures, a series of inventions in connection with the operation of life boats on shipboard. The subject was freely discussed and the speaker's communication was referred for publication. Adjourned

WM. H. WAHL, *Sec'y pro tem.*

The Franklin Institute.

(Proceedings of the annual meeting held Wednesday, January 15, 1908.)

HALL OF THE INSTITUTE,
PHILADELPHIA, January 15, 1908.

PRESIDENT WALTON CLARK in the chair.

Present, 204 members and visitors.

The President presented the following report of the Board of Managers covering the operations of the Institute for the year 1907:

Members of the Franklin Institute:

The Board of Managers has briefly to report that the work of the Insti-

tute was conducted during the year 1907 very much in the usual successful manner.

A year ago the Board reported progress in the work of the Franklin Fund and Building Committee, in its efforts to secure for the Institute a new home in a more desirable location, and with improved facilities. The Board is pleasel to be able to now report further that it has subscriptions for an amount sufficient for the erection of a new building, better suited to the work of the Institute than is the old house, and much more advantageously located. It has not, however, subscriptions to a sufficient amount to insure the erection of a building which would be not only suitable to the work of the Institute, but would be architecturally an appropriate memorial to Benjamin Franklin. The work of securing contributions is therefore being continued.

The Board is unable, just at present, to make the usual annual financial statement, because of unavoidable delay in securing an audit of the Institute's affairs. The Board will report to you at the earliest possible date, on the financial condition of the Institute.

The various Committees of the Institute have performed their duties in the usual satisfactory manner.

The Committee on Science and the Arts has awarded six Elliott Cresson Medals, has recommended the awa d of five John Scott Legacy Premiums and Medals, and two Edward Longstreth Medals of Merit, for meritorious inventions.

The Library Committee reports the addition to the Library of 1005 bound volumes and 324 unbound volumes, representing a valuable addition to the Institute Library.

The Sections have exhibited the customary activity during the past year, and the *Journal* thereby has been enriched by the publication of many important technical communications. We record with special gratification the award during the past year of the Boyden Premium to a deserving and talented Philadelphia scientist, Dr. Paul R. Heyl, for his most ingenious determination of the velocity of transmission of the rays of the ultra-violet portion of the spectrum.

The School Work of the Institute has been continued with success. The number of pupils in the Spring Term of the several schools was 163, and in the Winter Term 194, making a total of 357.

The Committee on Election and Resignation of Members reports the election of sixty-nine members during the year 1907.

In conclusion, the Board congratulates you that another year of useful life has been added to the honorable record of our venerable institution. The value of the work of Franklin Institute is appreciated highly and properly by our fellow citizens, as well as by the scientific men of the world. This has been again made apparent by the interest shown in our project for securing improved opportunities and appliances for useful work; and should encourage us to a new resolution that our Institute shall continue to be increasingly worthy to bear the name of Benjamin Franklin.

Personally, I thank you that you have thought safe to continue me in a position of responsibility in the honorable work of the Institute.

WALTON CLARK, *President.*

PHILADELPHIA, Jan. 15, 1908.

The report was accepted.

The paper of the evening was read by Mr. Patrick B. Delany, of East Orange, N. J., on the "Telepost." The speaker described an interesting development of his system of rapid automatic telegraphy, by which it could be applied advantageously to the postal service.

The system was exhibited in operation by a completely installed outfit of the apparatus employed, and the details were described with the aid of lantern photographs.

The subject was freely discussed.

At the close of the discussion the invention was referred to the Committee on Science and the Arts for investigation and report. The speaker received a vote of thanks for his interesting communication, which was referred to the Committee on Publications.

The Tellers of the Annual Election presented their report, which was accepted and the thanks of the meeting were tendered to them for their services. The result of the election was as follows:

For President,	(to serve one year).....	WALTON CLARK.
" *Vice-President,*	(" three years).....	WASHINGTON JONES.
" *Treasurer,*	(" one year).....	CYRUS BORGNER.
" *Secretary,*	(" one year).....	WILLIAM H. WAHL.
" *Auditor,*	(" three years).....	WILLIAM H. GREENE.

For Managers (to serve three years).

JOHN BIRKINBINE,	WALTON FORSTALL,	ISAAC NORRIS, JR.,
JAMES CHRISTIE,	LOUIS E. LEVY,	COLEMAN SELLERS, JR.
THOMAS P. CONARD,	RICHARD WALN MEIRS,	

(To serve two years.)
CHAS. E. RONALDSON.

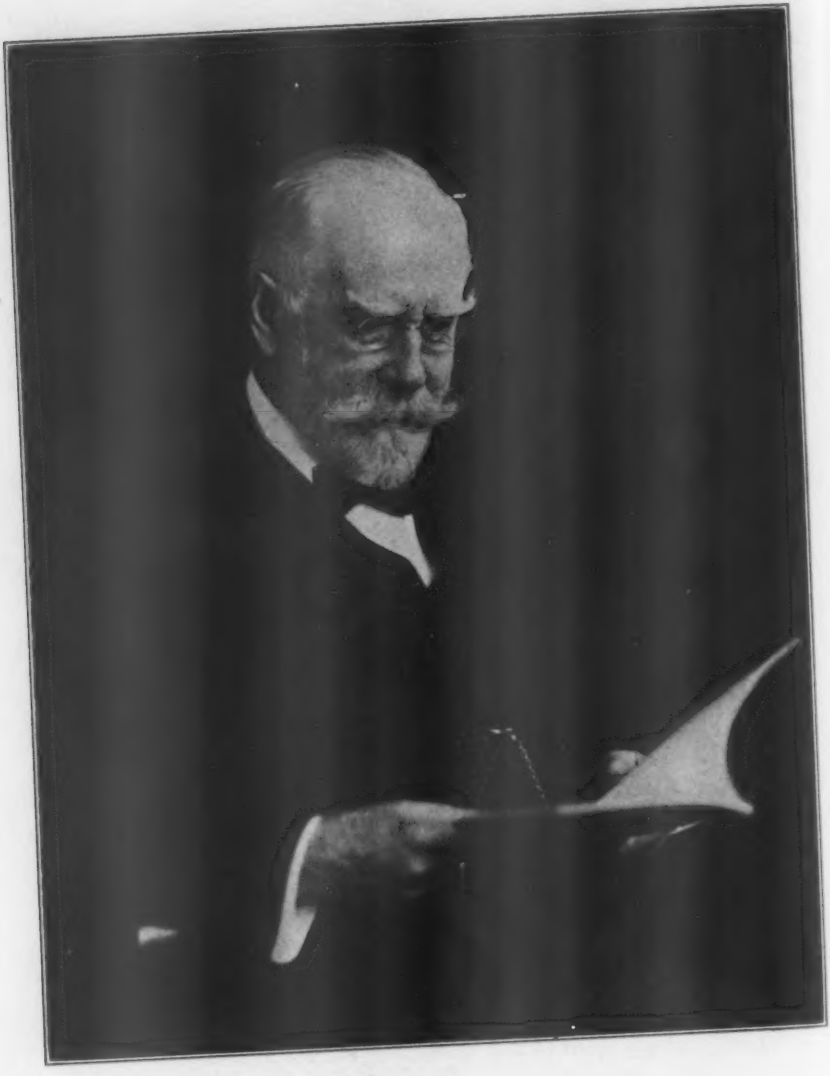
For the Committee on the Science and the Arts (to serve three years).

A. W. ALLEN,	EDWARD GOLDSMITH,	JAMES S. ROGERS,
CARL G. BARTH,	CASPAR WISTAR HAINES,	E. ALEX. SCOTT,
HUGO BILGRAM,	CLARENCE A. HALL,	HARRISON SOUDER,
FRANK P. BROWN,	LEWIS M. HAUPT,	MARTIN I. WILBERT,
KERN DODGE,	ROBERT JOB,	RICHARD ZECKWER,
W. C. L. EGLIN,	G. H. MEEKER,	CHAS. J. ZENTMAYER.
J. LOGAN FITTS,	LUCIEN E. PICOLET,	

(To serve two years.)
EUGENE S. POWERS.

Adjourned.

WM. H. WAHL, *Secretary.*



Yours faithfully
Edmund Tellus